COMPOSITE BULKHEAD FABRICATION DEVELOPMENT

Final Report

Contract No. NAS 8-11900
Control No. 1-5-30-12503(2F)

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By

THE BOEING COMPANY

Wichita Branch

Wichita, Kansas 67210

Prepared for:

George C. Marshall Space Flight Center
National Aeronautics & Space Administration
Huntsville, Alabama 35812

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By Raymond F. Cox

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SUMMARY OR ABSTRACT

The primary objective of this effort was to design, fabricate, and evaluate by empirical analysis a Composite Bulkhead produced by a fabrication concept utilizing vacuum and/or autoclave pressure to hold preformed (welded) sandwich elements in place during bonding and aging. This objective was successfully achieved.

The work included a minimum of design for the 105-inch diameter Composite Bulkhead for the purpose of approaching space flight type hardware upon which the principal objective (evaluation of dimensional behavior) could be accomplished. Accordingly, the bulkhead was designed and fabricated from 2219 aluminum alloy skins chem-milled on one side only to a .060 inch thickness except in the weld land areas where they remained a nominal .090 inch thickness. The outer skin was assembled by welding eight (8) stretch-formed and chemically-milled gore segments into a welded skin assembly slightly smaller than the concave bonding and aging tool.

Final form was fixed in the approved concave forming and aging tool by age forming the outer skin under vacuum and 60 PSIG autoclave pressure at 325°F. for 16 hours. A honeycomb core of one-inch thickness HRP (heat resistant phenolic) was bonded to the outer skin with Bloomingdale HT-424 Adhesive film cured at 325°F. for one hour at 30 PSIG autoclave pressure. The inner skin was final formed against the core at 60 PSIG autoclave pressure for 16 hours at 325°F. and then bonded to the core with HT-424 Adhesive for a one-hour cure period. NOTE: No core machining operation was required or performed.

Additional cure and aging time of 6 3/4 hours was applied to the inner skin and assembly to approach the desired minimum inner skin aging time of 24 hours to provide maximum corrosion resistance to the alloy. Measurements of the welded skin assemblies were taken in the free state, under vacuum, after aging, and after bonding into an assembly and were compared with the inside contour of the concave bonding and aging tool as the dimensional base.

The concave bonding and aging tool made from glass fiber reinforced epoxy plastic not only withstood the vacuum and autoclave pressures at temperatures but also proved to have relatively the same linear coefficient of expansion of 12.5 X 10^{-6} in./in./°F. as the 2219 Aluminum alloy skins when heated to approximately 344°F. An aging growth allowance of .001 in./in. for the 2219 aluminum alloy was the only compensation made in the Plaster Masters used to establish dimensions, tool contours, and adaptation for welding.

Two bulkheads were fabricated, measured, radiographically and visually inspected, and coin tap tested. One bulkhead was destructively tested by destructive separation of the skin from the core. The other bulkhead was delivered to MSFC in the concave bonding and aging tool.

Although the delivered bulkhead was not required to possess actual dimensions within working tolerances of the bulkhead design dimensions, in most cases it met normal tolerances except for trim allowances. No machining of the core was required to achieve proper fit.

It appears feasible to produce large-scale composite bulkheads whose actual dimensions will meet production tolerance requirements if the techniques, conclusions, recommendations, and technical data obtained from this effort are properly utilized by the personnel designing or fabricating the larger-scale bulkheads.

The aluminum alloy, 2219, or other comparable age formable skins should be used with a honeycomb core of sufficient strength to withstand the minimum of 60 PSIG pressure required for age form final contouring of the skins. The skins should be simultaneously age form contoured (with dummy thicknesses to represent the core and/or the adhesive thickness) in order to reduce the time at temperatures of 325°F. imposed upon the core.

The bulkhead design should allow for bulge (water pressure) forming* the skin segments. The trimmed outer skin shell after welding should either omit a definite skirt area or the skirt area shape should provide for the function of draft angles similar to those used on forgings in order to permit full entry and removal of the shell or bulkhead from the concave forming and aging tool.

Possible selection of fine grain T4 condition or annealed material as the starting condition may be advisable to avoid non-uniform or excessive grain growth if skins cannot be preformed from T37 condition material. Close tolerance coordination of tooling and suitable weld land design will be

*or other equally satisfactory method of preforming required to assure proper weld land widths after final trim of segments for welding. Care in removing weld beads adjacent to the core is necessary for maximum bond strength.

It appears that the perennial problem of skin-to-core mismatch now plaguing industry efforts on composite structures was overcome in this instance and the findings and techniques from this effort are offered in behalf of future Composite Bulkhead Fabrication Development efforts.

Although this effort concerned 2219 aluminum alloy, Boeing experience with 6Al4V titanium alloy indicates that its age formable characteristics would be adaptable to a similar fabrication concept for composite structures by utilizing higher age forming temperatures and appropriate tools. Confidence in the potential success of such a future effort is sufficient to propose that future components incorporate both upper and lower bulkhead segments and the cylindrical side skin into a single "canoe" shaped composite structure.

The Boeing Company is interested in any future efforts toward extending the state-of-the-art on composite structures.

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FOREWORD

This technical report covers the work performed from March 26, 1965, through November 24, 1965, under George C. Marshall Space Flight Center Contract NAS 8-11900 dated March 25, 1965.

This contract was conducted by The Boeing Company, Military Airplane Division, Wichita Branch.

The work was performed under the direction of A. Virgil Gerstner (Manager), R. E. Layton (Unit Chief, Tooling-Metalworking-Metallurgy), and H. O. Meserve, Jr. (Unit Chief, Chemistry Unit) of the Manufacturing Development Section, by Raymond F. Cox, Project Engineer.

The contract was initiated by Program R&D Branch of Marshall Space Flight Center and was administered by Lloyd Bowers, Technical Representative, and Charles Irvine, Technical Representative - Industrial Support Branch, Manufacturing Engineering Laboratory.

SCOPE OF WORK

Contract NAS 8-11900 was initiated to produce and evaluate a Composite Bulkhead utilizing a fabrication concept which uses vacuum and/or autoclave pressure to hold preformed sandwich elements in place during age forming and adhesive bonding.

The work included a minimum of design (Fig. 1) for the Composite Bulkhead to provide the hardware upon which the principal objective (evaluation of dimensional behavior) could be accomplished.

Included in the Scope was the design and fabrication of a concave forming and aging tool in which the 2219-T37 aluminum alloy sandwich face sheets could be final sized during aging to the T87 condition. The tool was to be of sufficient strength and stability to withstand vacuum and autoclave pressures at temperatures required during aging of the face sheets and subsequent adhesive bonding cure cycles.

The work further included fabrication of associated tooling required to produce the detail parts along with the assembly of such parts into the Composite Bulkhead Assembly.

Further, the effort included the evaluation of the completed assembly through empirical analysis, radiographic inspection, destructive and visual inspection.

WORK PERFORMED

Introduction

The Boeing Company was requested to furnish the necessary personnel, facilities, equipment, and materials for the purpose of empirical analysis and evaluation of a Composite Bulkhead fabrication concept which utilizes vacuum and/or autoclave pressure to hold preformed (welded) sandwich elements in place during bonding and aging.

Previous background experience allowed Boeing to readily subscribe to the possible advantages of the proposed fabrication concept. This was particularly true where the final forming and aging of the welded face sheet is performed under tensile stress similar to age forming. It was felt that the combination aging, weld stress relief, and bonding operations would minimize final dimensional distortion and permit closer dimensional control.

The tooling concept employed a plaster master as the means of transferring the drawing dimensions to hardware. Splashes with appropriate allowances for bulkhead component thicknesses were used to transfer detail part contours for tooling.

The exact dimensions of the "concave forming and aging tool" were used as the dimension base for comparative measurements under vacuum and in the free state.

The skin gore segments were pre-formed by stretch forming in the .090" thickness and subsequently chemically milled to remove .030" material to create skins (face sheets) of .060" thickness and having weld lands of .090" thickness.

The segments were rough trimmed and slightly chemically etched in preparation for welding. Final trim occurred on the weld fixture, Figures 3, 17, and 18. Tungsten Inert Gas welding of the skin gores into a shell was accomplished with an automatic heliarc wire fed welder adapted to follow a path dictated by the curvature of the skin and controlled by a weld fixture noted above.

Radiographic inspection of the welds was conducted and defects repaired as necessary.

The welded inner and outer face sheets, each consisting of eight solution heat treated 2219-T37 aluminum alloy gore segments stretch formed slightly undersize with respect to the "concave forming and aging tool" were trimmed to remove the weld bead from the surface adjacent to the core. The outer facing sheet was mounted in the "concave forming and aging" tool and partially aged in an autoclave to 'set' the contour under pressure and heat after which distortion was checked in relationship of face sheet to tool.

Pre-formed 1" thickness HRP honeycomb core was applied in sections, assembled, trimmed, and temporarily removed to permit re-cleaning and re-installation of the outer face sheet. HT-424 Adhesive (American Cyanamid) was applied to the face sheet and the previously prepared HRP Core was positioned on the adhesive surfaced face sheet. The Autoclave was used to apply pressure and heat to bond the outer core to the face sheet while the face sheet was held in intimate contact with the "concave forming and aging" tool.

The inner face sheet was mounted against the bonded HRP Core and again the tool was placed in an autoclave where the inner face sheet was partially aged to "set" the contour under pressure and heat. After cleaning, HT-424 Adhesive was applied to the inner face sheet prior to positioning it against the previously bonded HRP Core. Autoclave pressure was again used to provide heat and pressure for cure of the adhesive while the previously bonded core-face-sheet subassembly was held in intimate contact with the "concave forming and aging" tool.

Dimensional, radiographic, and visual analysis of both assemblies along with destructive testing of one assembly was accomplished. "Coin Tapping" was accomplished upon both assemblies.

Design of Bulkhead

In accordance with Article 11.3.n. of the RFQ, a minimum of design was required to be developed as the principal objective was the evaluation of the concept of dimensional behavior. Face sheet weld land areas were designed to maintain a strength level equivalent to the parent skin metal strength. The land areas were provided on one side of the face sheets only (away from the core-to-skin interface). (See Fig. 1).

For purpose of economy, it was determined to utilize chemical milling to remove the .030 inch material outlined by the weld lands, and the taper from the weld land to the .060 inch skin thickness was altered to allow the chemically milled depth of .030 inch to result in a .030 inch radius at the weld land base.

Design and Fabrication of Tools

All tooling and fixtures employed in fabrication for this study utilized materials and approaches intended to minimize cost in conformance with Article 11. 3.p. of the RFQ. In the case of the basic Plaster Masters, they were fabricated to permit multi-purpose operations progressively throughout the program. The "concave forming and aging" tool was the only tool for which a tool design drawing was required. (See Figure 2) However, for control and continuity of purpose, design drawings were prepared for the plaster masters and their subsequent adaptation as welding jigs. (See Fig. 3.) Other drawings used were not included in report. The balance of the tools that referenced from the Plaster Masters were fabricated from written planning instructions. Therefore, the Engineering Master Layout (developed from basic contour formulae, Fig. 27) was converted directly to sweep template controlled Plaster Masters from which splashes and material thickness allowances were transferred from the Plaster Master (PM) to control the desired part or assembly dimensions.

Plaster Masters --

Accordingly the tooling phase began with the planning and fabrication of two Plaster Masters. The (X) in the tool code indicates experimental, (PM) Plaster Master, and the number preceding the tool code separates tools of like code.

One Plaster Master, 1XPM-MR&T-SK717B, was fabricated to represent the inner surface of the "Concave Forming and Aging Tool" (Fig. 8, Fig. 9, Fig. 10). A female plaster splash was removed from the Plaster Master, Fig. 10. A male plaster splash was removed from the female spash, Fig. 11, for use in fabrication of the "Concave Forming and Aging Tool" (Fig. 16).

After the above splashes were removed from the Plaster Master, the "PM" surface representing the inner surface of the "Concave Forming and Aging Tool" was removed by chipping away the surface material.

The chipped area was refaced with a new surface representing the inner face of the outer skin to prepare the Plaster Master for its final function as a welding fixture for the outer skin - MR&T-SK717B-1, Fig. 3, 17, & 19. The second Plaster Master (2XPM-MR&T-SK717B) was fabricated to represent the inner surface of the inner skin in the same manner as the first PM.

See Fig. 27 for contour formulae used for fabrication of Sweep Templates used to create Plaster Master surfaces.

In conformance with Article II.3.p. of the RFQ (Cost Minimization), the Plaster Masters were adapted as welding jigs for the skin gore section joining operations. (Fig. 17, Fig. 18, Fig. 19.)

Stretch Form Tools --

Plaster splashes were removed from Plaster Master surfaces representing the inner surface of both the inner and outer skins. Using these plaster splashes with which to transfer the appropriate contour surface, stretch form tools were completed (Fig. 13 & Fig. 14).

It was determined early in the program that the chemical milling approach would be used to create the weld lands. This resulted in allowing stretch forming of the inner skins as opposed to the originally considered bulge (water) forming. Forming prior to chemical milling permitted a smooth controlled surface of the skins to bear against the tool contour.

Chemical Milling Templates, Trim Tools, and Core Forming Tool --

Plaster splashes were made from the appropriate surface of the Plaster Master and used to fabricate the outer and inner skin Chemical Milling Templates, the outer and inner skin Trim Tools, and the Female Core Forming Tool.

In the instance of the chemical milling templates and the Trimming Tools, no attempt was made to perfect the coordination between them and they were somewhat lacking in that final trim of the Polar Cap opening resulted in narrow weld lands. Dimensional behavior and structural integrity of the bonded assembly as related to the fabrication concept being the primary objective, it was deemed uneconomical to develop closer tolerance control of tools not directly resulting in beneficial information. Skins for both bulkheads, therefore, had similar weld lands. It should be noted, however, that weld land design and tooling must be coordinated to assure minimum weld land width after final trim.

A minimum concept forming tool was fabricated with which to pre-form the HRP Honeycomb Core into 8 gore shaped sections. The tool was made of laminated Hi-Temperature Epoxy Resin impregnated glassfiber - the same as the "Concave Forming and Aging Tool".

Concave Forming and Aging Tool --

See Design Drawing XBAJ-MR&T-SK717B - Bonding Jig - Composite Bulkhead (Fig. 2 and Fig. 15) for detail information.

See Fig. 16 for photograph of completed tool.

Fabrication of Detail Parts

The outer and inner skin gore sections were stretch formed to contour on a Hufford A-46 Stretch Press. Difficulties were encountered during initial stretch forming attempts. The required contour could not be obtained by stretching the 2219 aluminum alloy in the T37 condition. Successful forming was, however, accomplished with 2219-T37 aluminum alloy re-solution heat treated at 995°F. ±10°F. for a minimum of 35 minutes and subsequently water quenched. Initial efforts were accomplished upon 2219-T37 material on hand prior to receipt of project material from the mill. Evidence of grain growth appeared on the solution heat treated-stretch formed material.

A discussion (Telecon) with Mr. Bob Adamo, of the Reynolds Metals McCook Plant, resulted in his expressed opinion that solution heat treated 2219 annealed or 2219-T37 (subsequently stretch formed)(although possibly experiencing minor grain growth) would not present a major problem.

In consideration of our experience and his opinion, an attempt was made to change our Purchase Order from 2219-T37 to 2219-T31. However, the mill was too far along in the production of the project material to make such a change.

Due to the intent of this project to check the dimensional behavior of the concept, agreement was obtained from MSFC to proceed with solution heat treatment of 2219-T37 aluminum alloy. Certain 'orange peel' appearance occurred after stretch forming. Laboratory analysis of a section removed from an area representative of this condition indicates that the large grains were produced as a result of critical deformation (cold reduction of skin thickness at the mill) and re-solution heat treatment. It appears that the best way to have eliminated this condition would have been to purchase the finer grained 2219-T-4 or annealed material (Fig. 5).

Tensile test specimens were removed from a skin gore section that was solution heat treated, stretch formed along with the gores for the Bulkhead and subsequently aged for 24 hours at 325°F. ±10°F. (Fig. 4).

After stretch forming the skin gore sections, they were rough trimmed in preparation for chemical milling of the gores to create an .060" thick skin with weld lands around the gore periphery of .090 inch thick.

A coating of Chemical Mill Maskant (Turco #504 - Turco Products, Inc., Wilmington, California) .008-.010 inch thick was applied to each gore section, by dipping. The area to be etched was un-masked and the gores inserted in Turco Etchant 13B for completion of the chemical milling. The gores, rinsed and dried, were ready for final trimming.

Trim Jigs, fabricated to transfer trim lines from the Plaster Masters to the gore sections, were found to be inadequate in tolerance control. Due to the limited number of parts involved and to the nature of the study, the trim jigs were used only to trim the gores slightly oversize on the edges to be welded and net at the polar cap and skirt edges. Final trim of the edges to be welded was accomplished with the traveling head of the weld adapter of the appropriate Plaster Master. This was accomplished by substituting a 1/4 inch Quackenbush Hand Router in place of the Welding Torch. (Fig. 17, Fig. 18, Fig. 19.)

The edges to be welded were trimmed via this method to tolerances providing a maximum edge gap between gore sections (before welding) of .030 inch. Only in isolated areas did the gap exceed .030 inch and when this occurred weld problems were encountered. See "Bulkhead Welding".

Although a production article would be expected to use closely developed trim tools and consequently receive precision trim lines, developmental trimming indicates that both the inner and outer skin should be fabricated with excess material at both the Polar Cap and the Skirt areas to allow for final trimming. This was evidenced by narrow weld lands occurring after trim of these areas.

Also, a contributing factor was the problem of precision location of the inner skin with relationship to the outer skin especially during final insertion of the inner skin into its seat against the HRP Core. More about this item in the "Aging and Adhesive Bonding Section".

Bulkhead Welding

It was emphasized in the early stages that the purpose of this project was to prove the feasibility of composite structure for a simulated bulkhead; not to re-investigate process parameters for welding 2219 aluminum nor to evaluate "hard" tooling versus "soft" tooling for weld fixturing. Therefore, with a production run of only two assemblies, the decision was made to use the Gas Tungsten Arc (GTA) Welding Process, "soft" tooling, and a mechanized torch carrier with a mechanical roller arc length control only. This was done, inasmuch as the building of "hard" precise tooling with an automatic contour following, voltage controlled welder would have been both time-consuming and expensive.

All welding was accomplished with the GTA-direct current straight polarity helium shielded welding process. The welding speed was 20 inches per minute. The arc length was maintained by a roller traveling immediately in front of the welding torch. This voltage (approximately 14 V) was not constant because the soft tooling would allow localized "tenting" under the arc flame thereby reducing arc length. Stubbing (an electrical short produced by penetration of the welding wire into the molten puddle which automatically shuts down the operation) occurred several times.

Initially, weld backup was attempted by a flexible laminated stainless steel bar. The forementioned "tenting" problem cause the weld area to pull away from the back-up bar causing immediate burn-through. A change was initiated to use a fiberglass tape over a shallow fixed "U" groove with the molten metal cast onto the groove.

Manual arc welding was used to close some joints where gap exceeded .030 inch and for rework of all burn-through, cracks, etc.

Radiographic examination (Fig. 12) indicated linear porosity of all welds; however, the deficiency was not considered detrimental to the developmental effort and the decision was made to proceed.

The first completely welded outer skin assembly was considered unsatisfactory for further operations when visually observed. Warpage in the weld land areas were too prominent. Modifications were made to the Welding Plaster Master to provide hold-down straps to supplement the vacuum method of holding the gores in position. The originally welded skin was discarded and not used further.

A second outer skin was completed through the welding operation ready for age forming. An inner skin was fabricated in the same manner as the outer skin except the welding and control was accomplished on the inner skin Plaster Master. The interchangeable adaptor for welding was transferred from the Outer Skin Plaster Master to the Inner Skin Plaster Master.

Aging, Forming, & Adhesive Bonding

Prior to loading the outer face sheet into the Concave Forming and Aging Tool, all weld beads were removed from the surface adjacent to the honeycomb core and from the weld land side as necessary to assure proper fit in the Concave Forming and Aging Tool.

Metal removal was accomplished with a Zephyr Weld Shaver Model ZT509 (Zephyr Manufacturing Co., Inc., Inglewood, California).

The outer skin was positioned in the Concave Forming and Aging Tool and overlayed with a bleeder cloth and enclosed in a nylon plastic film which was sealed to the tool excess at the skirt edge.(Fig. 22). A vacuum of 26 inches Hg was created to force the skin against the tool. Molders-clay spheres were previously placed strategically in 72 positions between the skin and the tool. The skin was removed from the tool and the squeezed clay spheres were measured to determine amount of mismatch between the skin and the tool (Fig. 36).

Average space between the skin and tool at the skirt resulting from 24 measurements was .0283 inch. Average space at 24 locations approximately at mid-point between the skirt and polar cap was .0297 inch. Average space at 24 locations at the polar cap area was .0361 inch. See Data Sheet, Fig. 43, for summation of comparisons.

The outer skin was solvent-cleaned (acetone wipe) and positioned in the Concave Forming and Aging Tool. The skin was overlayed with a bleeder cloth and enclosed in a nylon plastic film which was sealed to the tool excess at the skirt edge (Fig. 22). A vacuum of 26 inches Hg was created between the tool and vacuum bag and the 'set-up' was tested to assure that no leaks were present.

The loaded tool was placed in an autoclave (Fig. 23) and pressurization began. At seven (7) PSIG positive autoclave pressure the vacuum was ported to the atmosphere and pressure was increased to sixty (60) PSIG. (See Fig. 28 for aging cycle.) Upon completion of the aging cycle (Fig. 20) the skin was removed from the tool and measurements were taken in the same manner as before.

Average space at the skirt was .0166 inch, average space at the center location was .0188 inch, and average space at the polar cap was .019 inch. See Data Sheet, Fig. 43, for Summation of Comparisons.

Previously preformed HRP Honeycomb Core was placed within the aged outer skin and final trimmed to assure proper fit for splicing. After removal of the fitted core, the outer skin was chemically cleaned by vapor (trichlorethylene) degreasing and etching it in Turco Etchant 13B to remove .0004-.0006 inch material from all surfaces.

The outer skin was repositioned in the tool using previously established index points to assure replacement of the skin in its original position of aging. HT-424 Adhesive (American Cyanamid Co., Bloomingdale Rubber Div.) was applied smoothly and evenly to the surface of the skin. The HRP Honeycomb Gore Sections were placed in position against the core and Foam Adhesive (Thermofoam 607 - Adhesive Engineering Co.) was placed in all core splices. The splice areas were covered with protective film and the assembly was prepared for aging in the same manner as was the outer skin.

The skin to core adhesive bonding cure cycle was accomplished in the autoclave using a positive pressure of 30 PSIG (Fig. 29). Preparation, bagging, and test of vacuum bag were handled in the same manner as for the outer skin.

Upon completion of the cure cycle the assembly was not removed from the tool. (Fig.21). The core was observed and the inner surface was determined to be smooth and of regular curvature that would not require machining.

At this stage, the welded inner skin was positioned against the HRP Core surface, bagged, and subjected to an aging cycle (Fig. 30) the same as was the outer skin. At this stage, the inner skin was removed from the outer skin—gore assembly and molders-clay spheres placed in the same relative 72 positions used for checking the outer skin.

The inner skin was repositioned in its location of aging (using the established index points) and (26) inches Hg of vacuum was again used to seat the parts in the tool. Upon removal of the inner skin the molders-clay spheres were found to be relocated within the core cells indicating intimate contact had been attained over the entire surface between the skin and core.

This being further proof that no core machining was necessary, the inner skin was chemically cleaned by using Turco Etchant 13B to remove .0004 to .0006 inch of material from all surfaces of the inner skin. HT-424 Adhesive was applied to the inner surface of the inner skin, and foam adhesive (Thermofoam

607) was added to core splice areas having insufficient amounts of foam.

The inner skin was lowered into the outer skin-core assembly which was not removed from the tool after the outer-skin-to-core bonding operation.

The lowering of the inner skin progressed smoothly until the last two inches of the skirt area reached the core at which time the adhesive on the skin tended to adhere to the core and movement of the skin ceased. A transparent nylon film was applied to the inner surface of the inner skin, sealed to the tool at the skirt edge, and vacuum was slowly drawn to force the skin into its final position. In this manner the inner skin slipped easily into position with the added advantage of capability to guide the skin into its proper place. Indications were that design consideration should assure that the structure at the skirt area does terminate without any length of wall closely paralleling the vertical centerline of the bulkhead. The assembled bulkhead was again bagged with a nylon film vacuum bag and subjected to autoclave pressure of 30 PSIG at 325°F for bonding, curing, and additional aging (Fig. 31). The vacuum bag was removed from the bonded assembly (Fig. 23) and the assembly was removed from the Concave Forming and Aging Tool (Fig. 24, 25, & 26).

Visual appearance was good. No unbonded "cans", indentations, etc. were noted.

The template (used for sweeping the original surface of the PM, from which the splash for the Concave Forming and Aging Tool was removed) was placed against the outer surface of the completed assembly. By shifting the template towards the polar cap, the template and assembly contours were noted to be in close proximity. By locating the template according to the originally established Template Master Layout trim line, the assembly contour was noted to deviate from the template beginning at the skirt trim line at .105 inch deviation which gradually disappeared to zero (0) deviation at 12 inches from the skirt trim line. Deviation again appeared at a point approximately 30 inches from the Polar Cap trim line and increased gradually until at the Polar Cap trim line the deviation was again approximately .100 inches. This condition could be compensated for by fabricating the assembly with excess material at both the skirt and polar cap areas to allow for trim lines to be located in relation to the final assembly curvature. Also, it would appear necessary that a new ellipse equation be used to compensate for stresses other than precipitation aging growth.

In analyzing the Measurements and Calculations (Fig. 43 & Fig. 46) taken of final fully aged part, it appears that the contour follows the ellipse equation of $X^2 + 2Y^2 = 52.5^2$ used on the scale bulkhead assembly MR&T-SK717B in that the required part and the fabricated part are in the family of ellipses whose axes coincided and the normal distance between parameters is constant.

The final part is slightly undersize (.020 inch) with a slight depression in the polar area. This deviation would indicate that physical or mechanical conditions prevented predicted growth during the aging and bonding treatment.

This may be rationalized as being due to difference in rate of expansion and/or contraction between weld bead material and adjoining material during the aging process.

Molding clay spheres were again placed in the forming and aging tool in the original 72 locations used for previous comparisons. The bonded assembly was positioned in the tool using previously used index points and the assembly was seated in place with (2) inches Hg vacuum. Vacuum was released, the assembly removed from the tool, and the compressed nodules of molders-clay were measured (Fig. 38).

The average space between the bonded assembly and the forming-aging tool at the skirt was .0196 inch. At the mid-point the average space was .0202 inch. At the polar cap area the average space was .0328 inch.

The set-up and measurements were repeated except that 24 inches Hg vacuum was used to seat the assembly in the tool (Fig. 39).

The average space between the bonded assembly and the forming-aging tool at the skirt was .0153 inch.

The average space at mid-point was .023 inch and the average space at the Polar Cap area was .025 inch. See Data Sheet Fig. 43 for Summation of Recordings.

The assembly was visually observed by combined Boeing and NASA representatives who agreed the results were highly encouraging and largely successful.

The second assembly was fabricated in much the same manner as the first except that autoclave pressures were reduced to 40 PSIG. The question had been raised as to the possibility of accomplishing the same results by use of atmospheric pressures or some pressure less than the 60 PSIG used for the first assembly aging. It was felt that reducing the pressure used on the second assembly to 40 PSIG could result in useful information without jeopardizing the intent of the study.

The aging and cure cycles for the second unit are represented by Fig. 32 thru Fig. 35 with comparative measurements represented by Fig. 40 thru 42.

'In process' measuring of the skins of the second assembly were reduced; however, complete measurement of the bonded assembly was accomplished the same as on the first assembly.

It may be noted that although approximately comparable results were obtained at the skirt area of each assembly, the results were poorer in the polar cap area. It may very well be that pressures greater than the 60 PSIG used on the first assembly would result in closer tolerance control.

Destructive Test, Radiographic Examination, and Specimen Testing

The first bonded assembly was subjected to radiographic examination (Fig.44) which showed the HT-424 Adhesive to be evenly distributed, splices well fitted and bonded. There were no crushed cells or node separations, and the general quality of the core was excellent.

Linear Porosity and lack of penetration were noted in the welds; however, none of the weld defects appeared to be more than 30% of weld thickness (Fig. 12).

Visual appearance of the assembly was such that it was determined that it would be set aside until completion of the second assembly at which time the assembly with the lesser quality, visually and empirically, would be chosen for destructive testing.

The second bonded assembly was subjected to radiographic examination (Fig.45) which showed the adhesive to be evenly distributed. Splices were well fitted and bonded. There were no crushed cells or node separation. The general quality of the core was good. Welding linear porosity and lack of penetration also appeared in the second assembly.

The second assembly as evidenced by Fig. 41, although still of good contour and well pressurized during its fabrication, had greater average deviation between the assembly and the tool, less retention of form and/or more dimensional change during the heating and cooling of the final adhesive bonding cycle. Therefore the second assembly was chosen as the unit to be destructed for visual observance of quality.

Destructive testing began with the sectioning of the entire assembly into pieces approximately 2.5 square feet in area, after which one skin was removed. The method of removal consisted simply of clamping one corner of a skin to a table and physically peeling the opposite skin from the core.

Observation resulted in the following comments:

1. Intimate contact was obtained between skins and core in all areas other than directly under the weld lands.

2. In all weld land areas where such weld lands were prepared without sharp contour deviation, unremoved excess weld bead, etc., the contact between core and skin was sound. It should be noted that the weld land areas are problem areas and this method will not compensate for sharp deviations of skin surface.

   Although the age forming of the skins tends to overcome some irregularities, there can be no substitute for adequate preparation of weld land areas on the core surface.

It should be noted that, during the welding problem period, a pair of gore segments of .090 inch thickness (not chemical milled to include weld lands) were welded. Indications were that less distortion, tenting, mismatch, etc., were encountered with the thicker material, weld land design should not only have adequate width to meet structural requirements but should be wide enough to transfer restraining pressures and to act as a heat sink.

3. Core splice areas, where the core was held in close proximity during the pre-splice preparation of the gore segments, resulted in good bonds and pressure patterns. Areas between core gore segments, which were incompletely filled during the adhesive bonding cure cycle of core-to-outer-skin and which received additional Thermofoam 607 at the time of final adhesive cure of core-to-inner-skin, resulted in poor adhesion of the added foam.

   It is surmised that this condition resulted from the original foam being subjected to the inner skin aging cycle prior to foam addition. Therefore, foam splice of core should be complete prior to aging of the inner skin, if such core is used as a separator during aging.

5. Although both skins were adequately bonded, the inner skin was the one that peeled from the core in nearly every case. This may be an indication that minor contamination may be resulting from volatiles being given off of the HRP core during the long aging cycle of the inner skin. Adhesive priming of the core may be necessary for maximum adhesion. These problem areas may be circumvented by using a slip sheet to replace the core during aging forming of both skins simultaneously.

Test Specimens were prepared and tested as follows:

In order to provide a means of comparison to determine the effect of long-time cycles at 325°F.: The aluminum used was 2219-T37 chemically-milled from .090 inch thick to .040 inch thick for lap shear specimens and .020 inch thick for peel specimen skins; the core was aluminum core. The peel test results should be contrasted to a minimum average requirement of 15 in.lb. per 3 in. width and the Lap Shear Test results should be compared to 1350 PSI average requirement.

One Set of Lap Shear Specimens and One Set of Climbing Drum Peel Specimens were prepared and cured with the outer-skin-to-core adhesive bond (Fig.33).

These specimens were also subjected to the inner skin age forming cycle and inner-skin-to-core adhesive bonding cycle. A second set of specimens was prepared and bonded only with the inner-skin-to-core adhesive bonding cycle (Fig.35).

The test results for the specimens subjected to multiple cycles are shown by Fig.6. Results of the specimens cured with final adhesive cure only are shown by Fig. 7.

Some deterioration is indicated to be induced by the long-time curing.

It is not inconceivable that the age forming of the outer and inner skin could be accomplished simultaneously, eliminating this effect.

It should be noted that with reduction in strength, the specimens exceeded typical minimum requirements of the adhesive bonding industry for this adhesive system.

<u>Comparison of Bulkhead Assembly to Tool at Skirt Edge</u> --

104.969 inches = Avg. Dia. of tool excluding weld land relief (Fig. 36 & 37).

104.9298 inches = Avg. Dia. of tool less Avg. Deviation between assembly and tool (Fig. 38) (104.9298 - .0196 - .0196 = 104.9298)

104.9898 inches = Avg. Dia. of Assembly -- 104.9298 + .060 (weld land thickness)

Reduction to forty (40) PSI autoclave pressure used for processing the second assembly appeared to have very little effect at the skirt area; however, the effect was more pronounced at the polar cap area. (See Fig. 43.)

It appears that a minimum of 60 PSI autoclave pressure is necessary and that more pressure may provide increased dimensional control and should be used consistent with core compression resistance capability.

Conclusions

1. The aluminum alloy 2219 can be pre-formed and subsequently age formed to tolerances required for adhesive bonded honeycomb sandwich structures.

2. The 2219 aluminum alloy skin gore segments for this design were not successfully stretch formed in the T37 condition.

3. Successful stretch forming was accomplished by re-solution heat treatment of 2219-T37 aluminum alloy.

4. Excessive grain growth resulted from the re-solution heat treatment combined with previous cold reduction that induced critical strain occurring at the vendor's facility.

5. Non-uniform grain size can be eliminated by starting the operation with the finer grained T4 condition or with annealed material.

6. Close tolerance coordination of tooling and suitable weld land design will be necessary to assure minimum weld land width after final trim and also to provide adequate heat sink for welding.

7. Aerospace quality welding was not accomplished with the minimum concept tooling used for this program.

8. Provisions will be necessary for the precise location of the inner skin in its proper position, prior to adhesive bonding it to the outer skin-core subassembly (particularly with respect to rotation away from the common vertical centerline).

9. Design consideration should assure that the structure at the skirt area does terminate without any length of wall closely paralleling the vertical centerline of the bulkhead for the same reason as draft angles are provided on castings and forgings.

10. Excess material should be provided at the skirt and polar cap zones with corresponding allowance of weld land width to provide Manufacturing with trim (pay-off) material.

11. Minimum aging and bonding pressures of 60 PSIG should be used; core of suitable compression resistance must be selected if higher pressures are used.

12. Close tolerance preparation of the weld land on the core side of the face sheet is necessary.

13. The adhesion of the inner skin to the core, although well bonded, was not as great as the adhesion of the outer skin to the core. Although the cause was undetermined, it may be attributed to the extended heating time the core receives during the inner skin aging cycle. The simultaneous performance of inner and outer skin aging prior to bonding could eliminate such potential problem area.

14. The close dimensional match of the skin to the core, achieved by the general concept suggested in the Request For Quotations, was superior to any techniques previously employed by or familiar to the contractor for bonding of large dual metal skin shells of compound contour.

15. The filleting action of the adhesive to the core did not appear to be as prominent on the HRP core as is normally viewed where aluminum core is used. This may be due to the insulative characteristics of the non-metal core. Although the destructive test showed adequate bond strength, it could perhaps be increased by use of heavier weight adhesive film. HT-424 Adhesive overlap, occurring in some areas, did not affect the core-to-skin pressure patterns but did appear to cause somewhat improved filleting action between core and skin.

16. Foam splice adhesive added during the core-to-outer-skin-to-core bonding operation, and later subjected to the inner skin aging cycle did not adhere properly to the foam-splice adhesive added during the inner-skin-to-core bonding operation. There appeared to be some non-visible contamination on the surface of the earlier cured foam adhesive, possibly from volatiles that may have been expelled by the long-time heating of the core.

Recommendations

It is recommended that:

1. This concept be further explored by design and fabrication of a complete large scale composite bulkhead, the design to include cylindrical-skin-to-bulkhead transition joint construction.

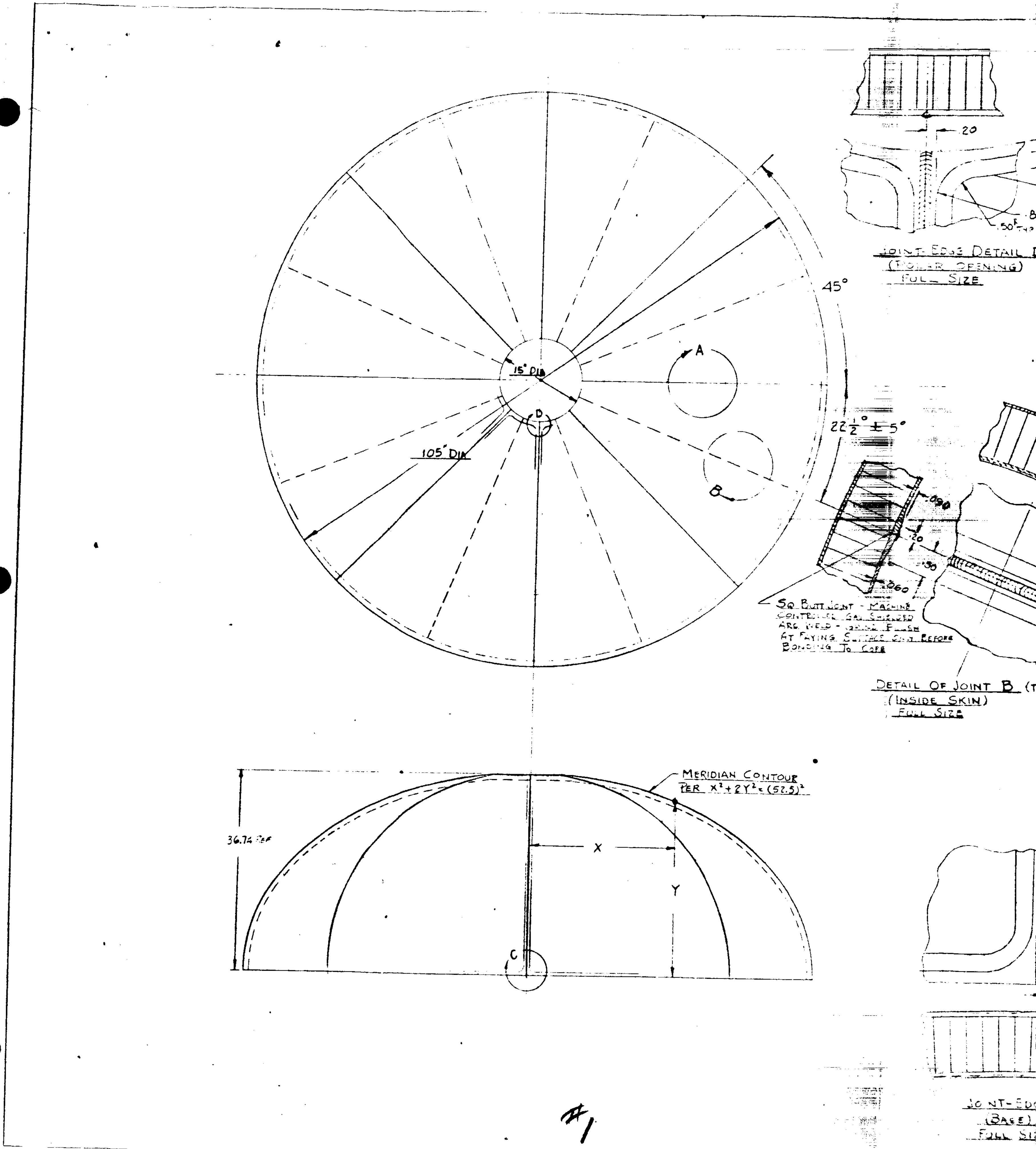
2. Such large scale assembly utilize the bulge forming or equally satisfactory method of pre-forming the skin segments.

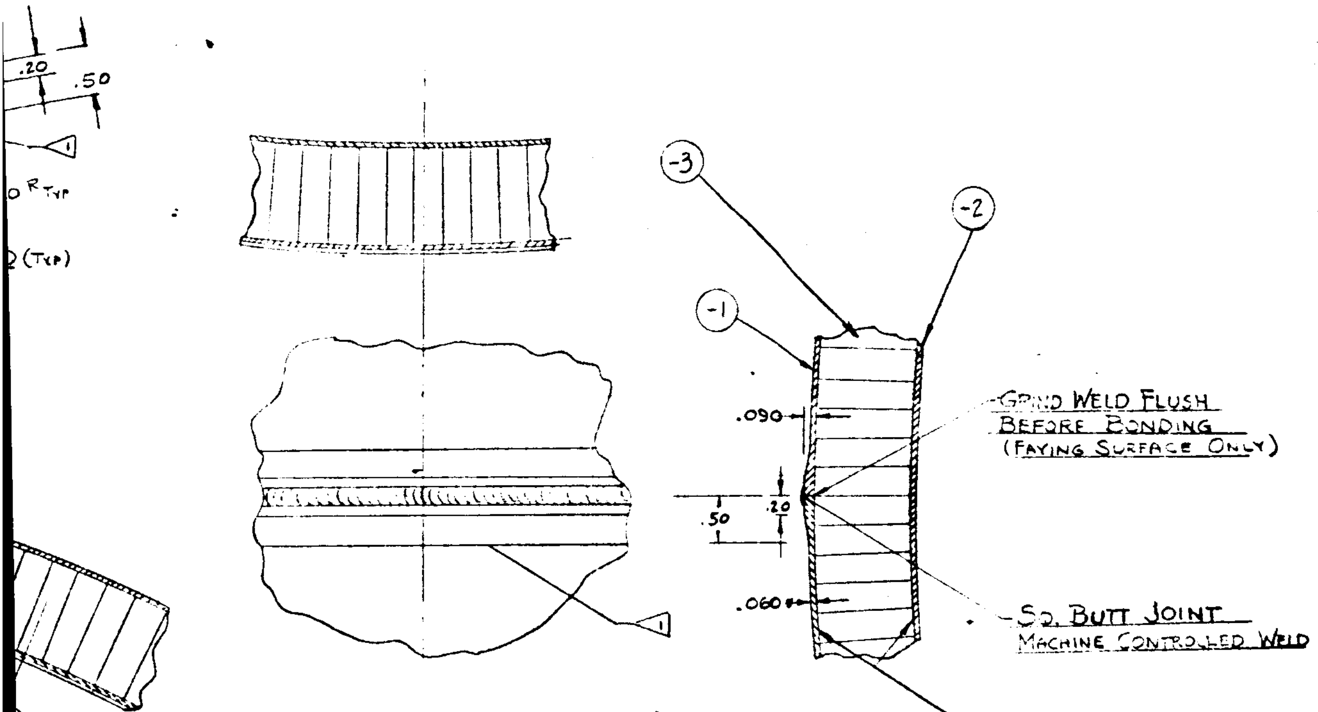
3. Age forming of both the inner and the outer skins be accomplished simultaneously with a separator sheet simulating the honeycomb core thickness. Such age forming to be done prior to the adhesive bonding stage. The age forming and adhesive bonding tool for large scale assemblies could encompass the general concept depicted by Fig. 47.

4. Investigation be made to determine insulative capability of perforated honeycomb core sandwich structures that have had a vacuum created within the core area between the face skins. Reduction of boil-off of liquid oxygen or hydrogen could result.

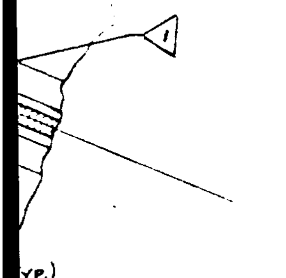
5. A study be made to prove feasibility of fabrication honeycomb sandwich structures with face sheets of 6Al4V titanium using the age forming approach to close tolerance fabrication. A cursory evaluation by Boeing-Wichita resulted in strong indications of feasibility.

6. A study be made to prove feasibility of age forming 6Al4V titanium face sheets in larger sections which would include not only an upper and lower bulkhead segment but also to include in the one piece, a cylindrical skin section. The shape of the resulting larger section would resemble a canoe having elliptical end segments.


.20
.50 TYP
JOINT EDGE DETAIL
(POLAR OPENING)
FULL SIZE
45°
A
15" DIA
D
105" DIA
B
22½° ± 5°
.090
.20
.30
.060
SQ BUTT JOINT - MACHINE CONTROLLED GAS SHIELDED ARC WELD - GRIND FLUSH AT FAYING SURFACE ONLY BEFORE BONDING TO CORE
DETAIL OF JOINT B
(INSIDE SKIN)
FULL SIZE
MERIDIAN CONTOUR PER $X^2+2Y^2=(52.5)^2$
36.74 REF
X
Y
C
(BASE)
FULL SIZE
#1



DETAIL OF JOINT A (TYP.)
(OUTSIDE SKIN)
FULL SIZE



2 BOND CORE TO SKINS WITH HT-424 (BOEING BMS 5-17)

1 RADIUS BLEND AT ALL SCULPTURE INTERSECTIONS

SKIN THICKNESS WITHIN ±.005

DECIMAL DIMENSIONS WITHIN ±.030

ANGLES WITHIN ±1° EXCEPT AS NOTED

SCALE 1/10 EXCEPT AS NOTED

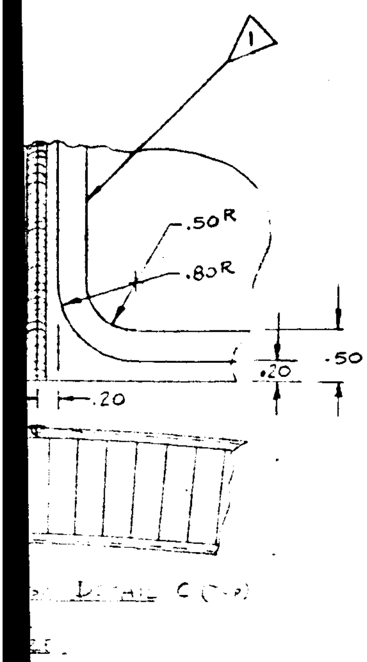


Fig. #1
78.57

-3		HRP 3/8 GF12-3.2	CORE	104 SQ FT x 1 IN THICK
-2	8	2219-T37 AL	INSIDE SKIN	.090 x 48 x 120
-1	8	2219-T37 AL	OUTSIDE SKIN	.090 x 48 x 120
PART No	No REQ'D.	MATERIAL	PART NAME	SIZE

DRAWING ORIGINATED BY
MANUFACTURING DEVELOPMENT

THE BOEING COMPANY
AIRPLANE DIVISION, WICHITA BRANCH

SCALE: PROJECTION:

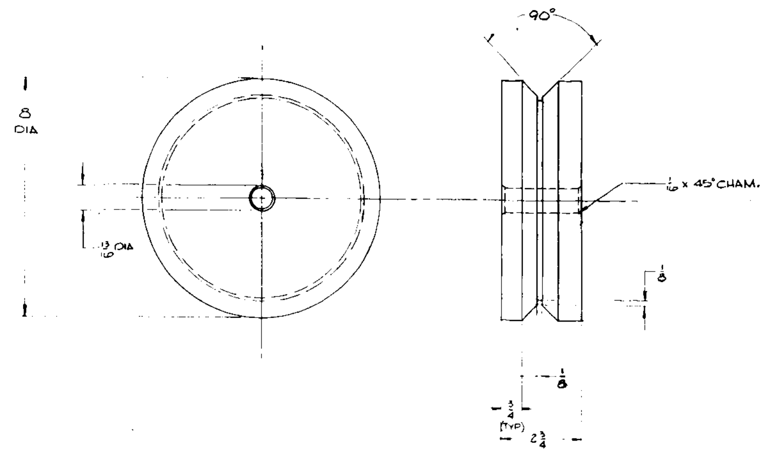
DRAWN BY
CHECKED BY
APPR. BY
APPR. BY

BULKHEAD ASSEMBLY
AND DETAILS

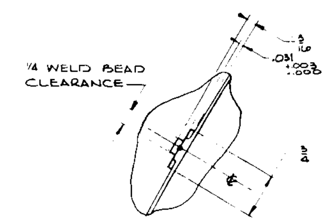
MRBT SK7..B

SHT. OF 1

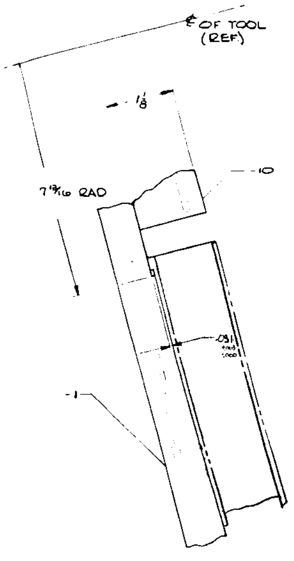
#2



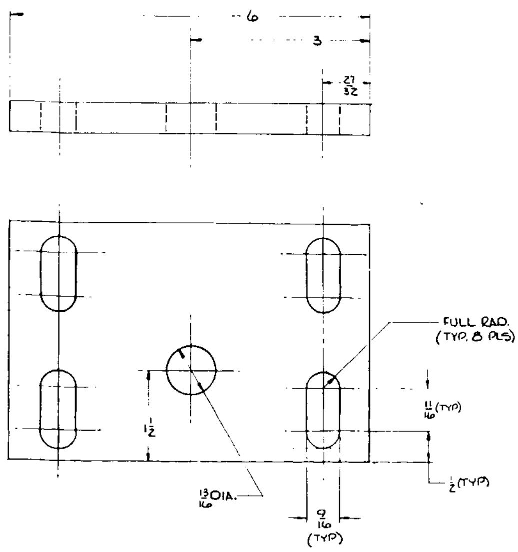
(3) WHEEL
HALF SIZE



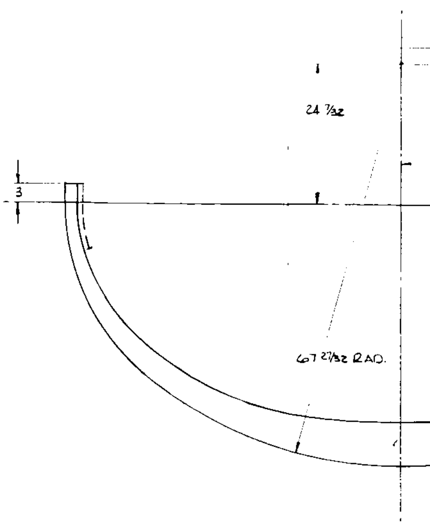
VIEW I
FULL SIZE



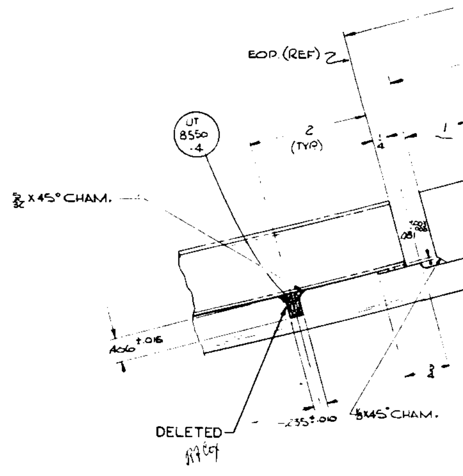
E — E
FULL SIZE



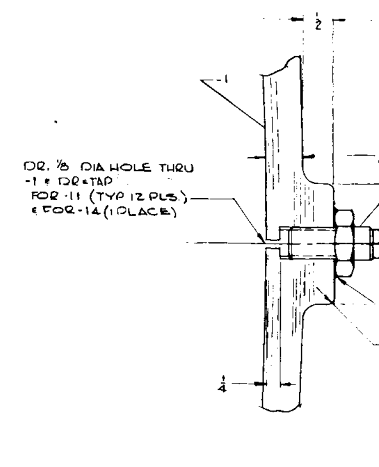
(7) WHEEL ADJUST PLATE
FULL SIZE



TYP GUSSET

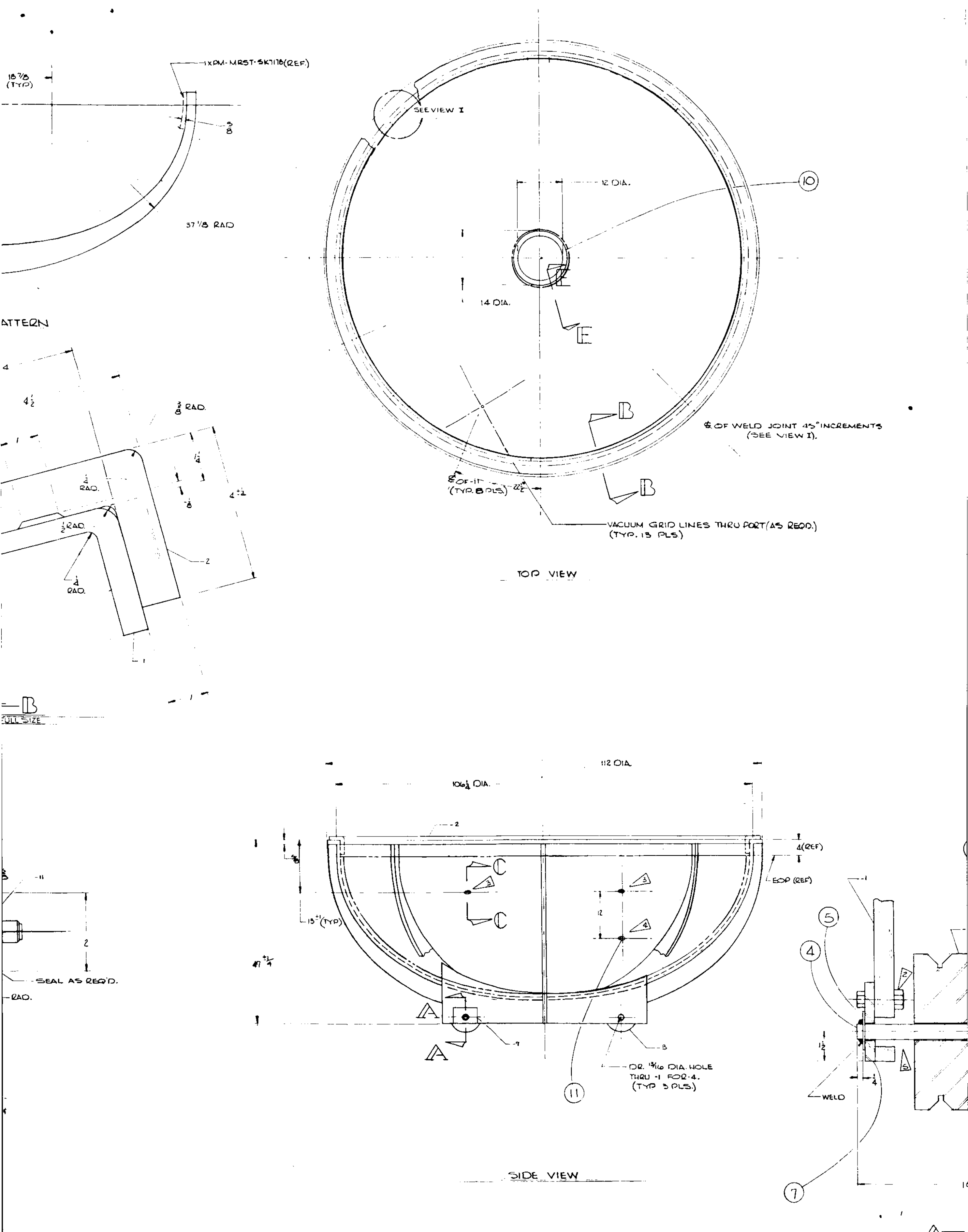


B —

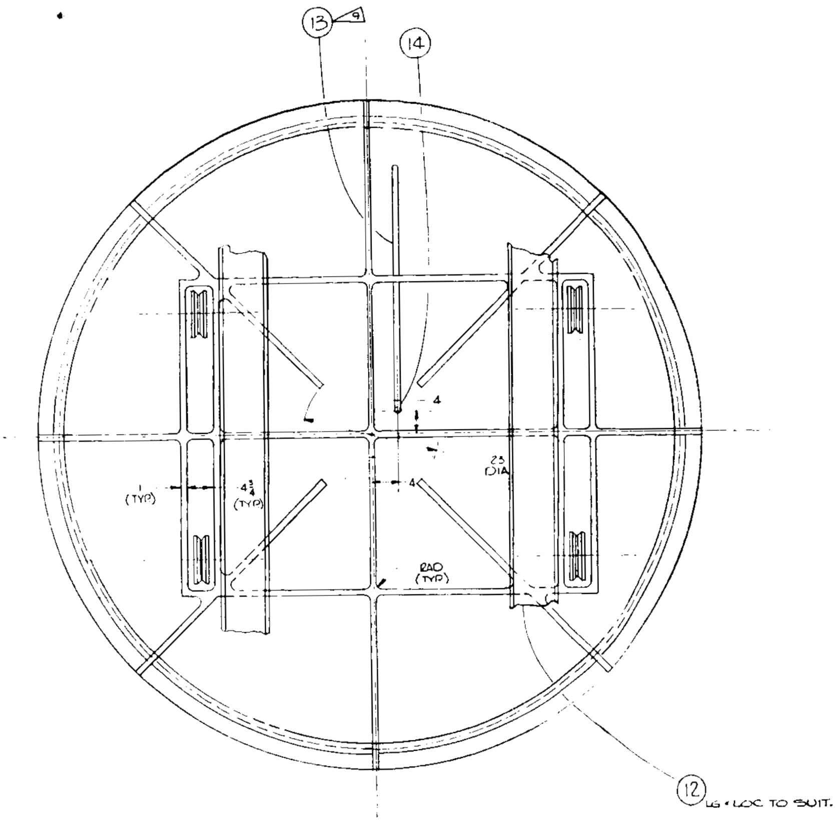


C — C
FULL SIZE
(TYP 12 PLS FOR -11
1 PLACE FOR -14)

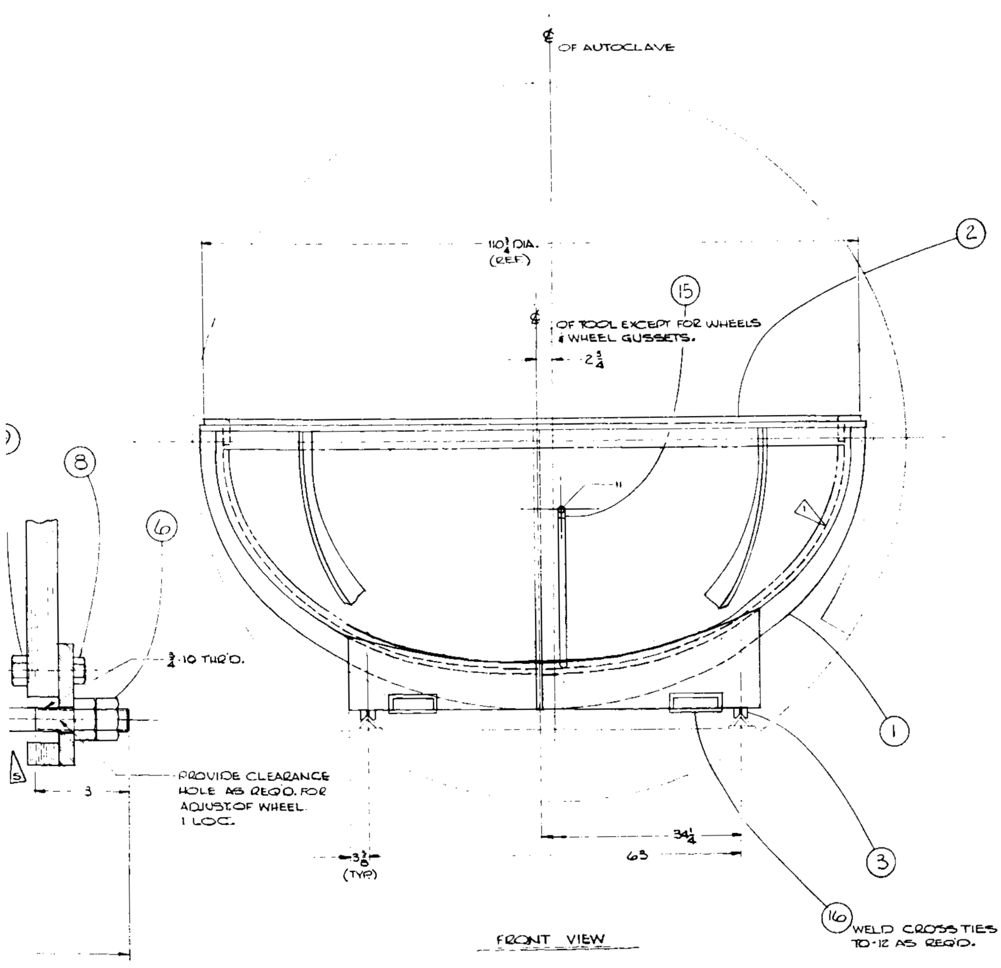
#1


1XPM-MRST-SK7178(REF.)
18 7/8 (TYP)
37 1/8 RAD
ATTERN
3/8 RAD.
1/4 RAD.
1/2 RAD.
1/4 RAD.
FULL SIZE
SEE VIEW I
12 DIA.
14 DIA.
10
E
B
℄ OF WELD JOINT 45° INCREMENTS (SEE VIEW I).
℄ OF -11 (TYP. 8 PLS) 22½°
VACUUM GRID LINES THRU PORT (AS REQD.) (TYP. 13 PLS)
TOP VIEW
112 DIA.
106¼ DIA.
4(REF)
EOP (REF)
13±1 (TYP)
C
A
SEAL AS REQ'D.
DR. 13/16 DIA. HOLE THRU -1 FOR -4. (TYP 3 PLS.)
11
SIDE VIEW
WELD
HALF

2



BOTTOM VIEW



FRONT VIEW

#3

2

FUNCTION:

1. TO AGE FORM OUTER SKIN.
2. TO LAYUP & BOND HONEYCOMB TO OUTER SKIN.
3. TO AGE FORM INNER SKIN.
4. TO LAYUP & BOND HONEYCOMB TO INNER SKIN.

NOTES:

DO NOT SCALE DWG.

BREAK ALL SHARP EDGES & CORNERS EXCEPT AS SHOWN.

IDENTIFY PER TPS.40.

1. C/D CONTOUR TO ⟶ IXPM-MRST-SK717B USING #1 SWEEP TEMP.
2. OPT. TO USE FLAT HD. SCREWS & PROVIDE C'SINK TO SUIT.
3. PROVIDE VACUUM CONNECTIONS ON 45° INCREMENTS STARTING 22½° FROM ℄ OF WELD BEAD.
4. PROVIDE GAGE CONNECTIONS ON 90° INCREMENTS.
5. SHIM IN THIS AREA AS REQ'D. WITH WASHERS OR CUT PIPE TO OBTAIN 63 DIM. & 34¼ DIM.
6. OBTAIN FROM MAINTENANCE STOCK.
7. GLASS CLOTH WITH MIDCON #500 RESIN & 510 HARDNER.
8. PERMISSIBLE TO FAB. FROM 3 OR 4 PIECES.
9. BEND TO APPROX. CONTOUR & ATTACH TO -1, YET ALLOW FREEDOM TO MOVE DUE TO HEAT EXPANSION.

* NON-STOCK ITEM.

	ASSY USED ON	DETAIL NO	QUANTITY	NAME OF DETAIL	ZONE	MATERIAL	STOCK SIZE
		UT8550	1	NEOPRENE VACUUM SEAL			-4 LG. TO SUIT
		16	AS REQ'D.	CROSS TIE		HRS	½ X 2 X 8⅞
6		15	1	ELBOW			½ PT
6		14	1	STREET ELBOW			½ PT
6		13	1	EXTENSION			½ PIPE X LG TO SUIT
		12	2	LIFT CHANNEL		HRS	8 X 2½ X 5/16 X TO SUIT
*		11	13	PLUG.		HANSON	4-TZ5
		10	1	SPACER RING		7	TO SUIT
		9	8	HEX NUT		STL	½-13
		8	8	CAP SCREW		HEX. HD.	½-13 X 2 LG.
		7	2	WHEEL ADJUST. PLATE		HRS	½ X 4 X 6⅛
		6	8	HEX NUT		STL.	¾-10
		5	4	AXLE RETAINER		IRON WASHER	¾ I.D. X 2 O.D.
		4	4	AXLE		HRS	¾ DIA X 10¼ LG
		3	4	WHEEL		HRS	8 DIA X 3¾ LG
		2	8	SPACER RING		7	TO SUIT
		1	1	BODY		7	TO SUIT

SCALE	ONE-TENTH & NOTED
ALL DIMENSIONS IN INCHES	
EXCEPT AS NOTED TOLERANCE	
FRACTIONAL ±	1/16
DECIMAL ±	.005
ANGULAR ±	1°
MACHINE FINISH	✓ SEE TDM
FLOOR AREA	—
APPROX WT	—
USED ON	AUTOCLAVE
WORK ORDER	576316
TBR OR SN	667857
DETAIL BY	R.J. PLUSH 5/18/65
CHECK BY	FORSTER 11/65
APPROVED	[signature]
APPROVED	[signature]
COLOR OR PROTECTIVE FINISH	—

TOOL DRAWING

THE BOEING COMPANY

WICHITA DIVISION • WICHITA 1, KANSAS

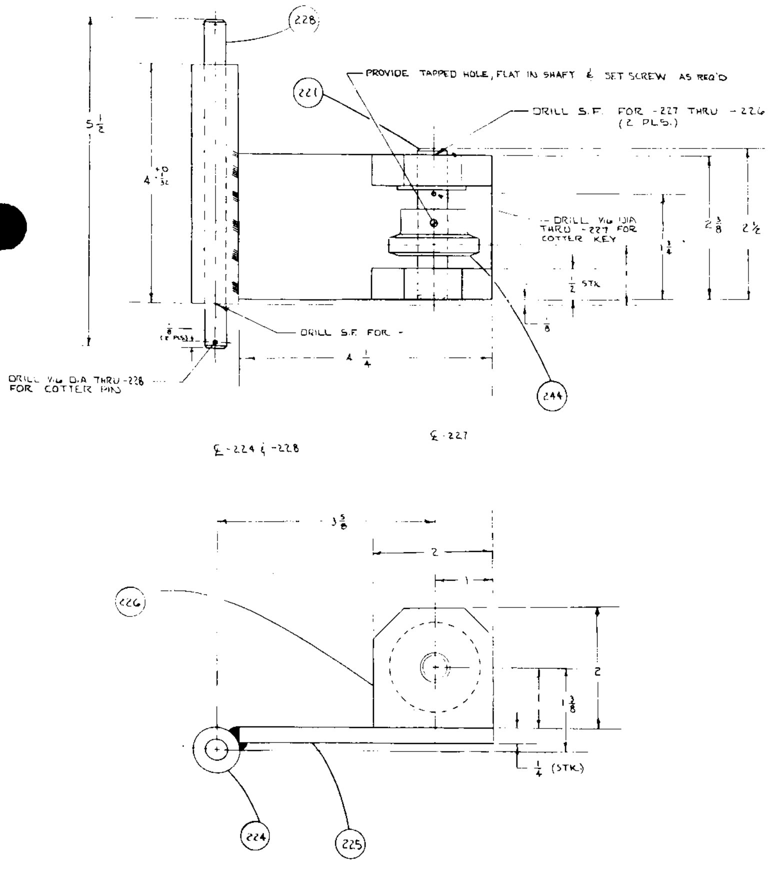
BONDING JIG
COMPOSITE BULKHEAD

XBAJ-MRST-SK717B SHEET —

MFG DEV.

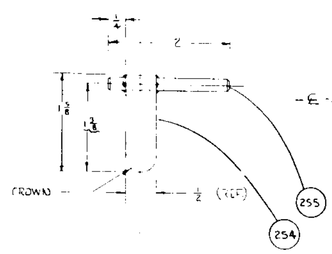
FIG 2

#4



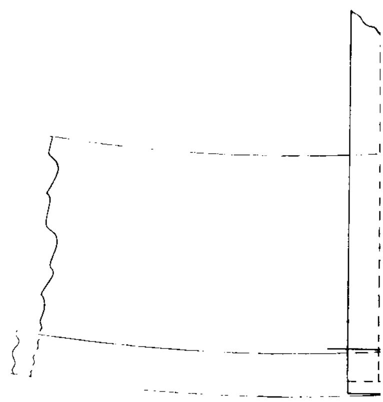
(223) IDLER ASSY DETAIL (2 REQ'D)

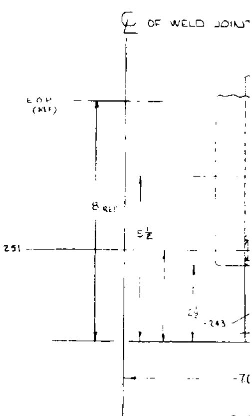
FULL SCALE



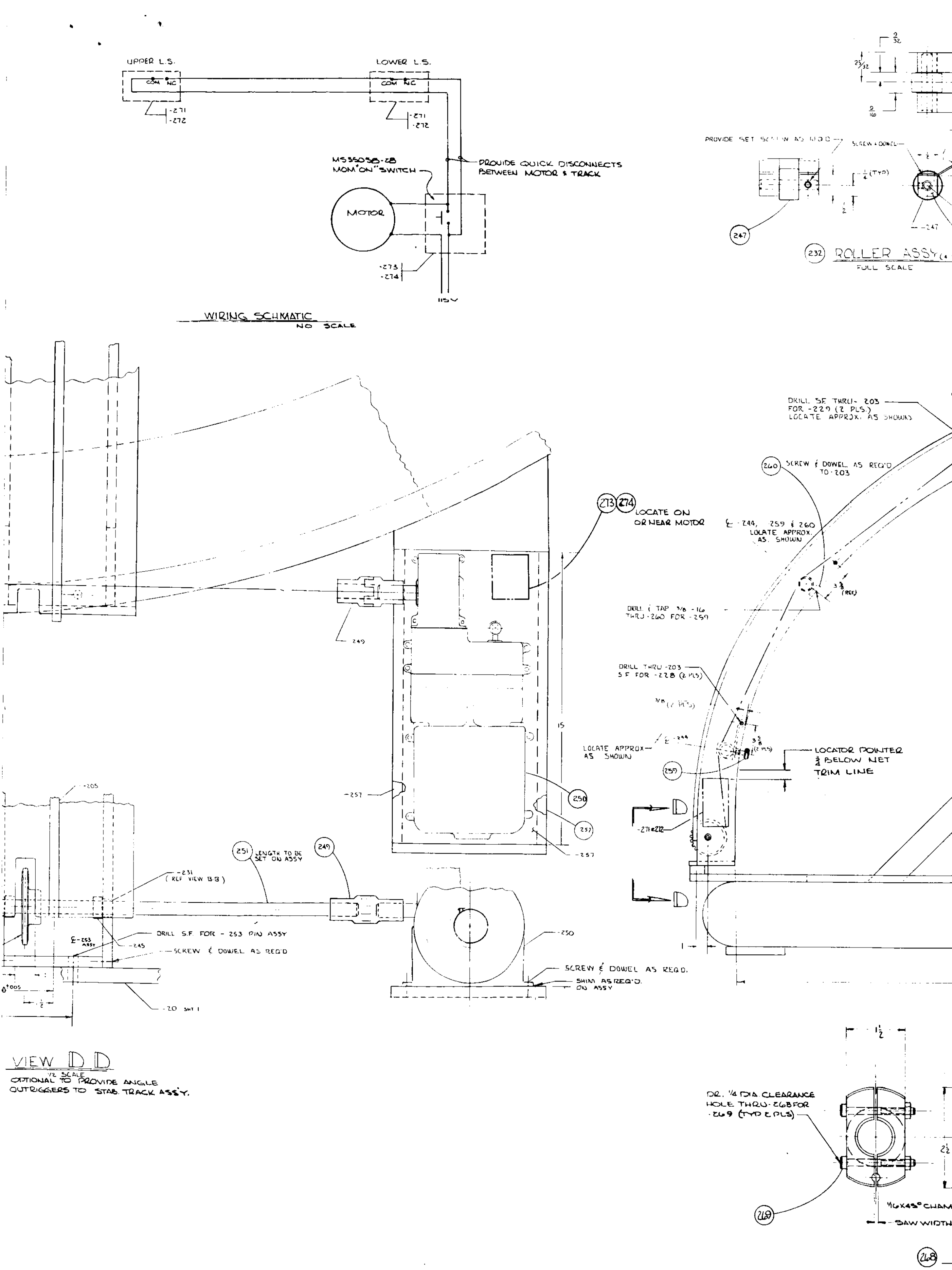
(253) LOCATING PIN

FULL SCALE



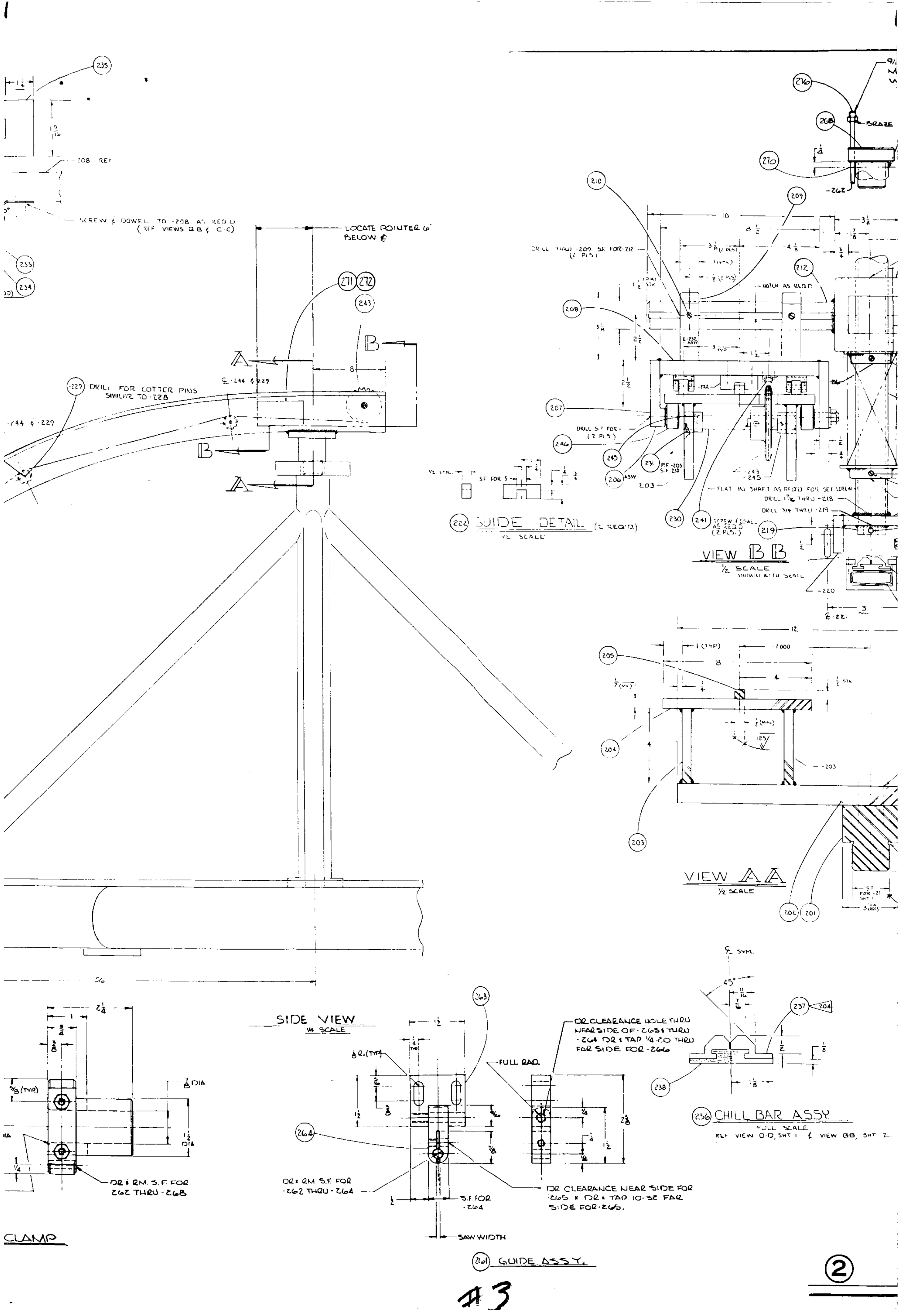


#1



UPPER L.S.
LOWER L.S.
COM NC
-271
-272
MS35058-28
MOM"ON" SWITCH
PROVIDE QUICK DISCONNECTS BETWEEN MOTOR & TRACK
MOTOR
-273
-274
115V
WIRING SCHMATIC
NO SCALE
PROVIDE SET SCREW AS REQ'D
SCREW & DOWEL
247
232 ROLLER ASSY
FULL SCALE
DRILL SF THRU -203 FOR -229 (2 PLS.) LOCATE APPROX. AS SHOWN
260 SCREW & DOWEL AS REQ'D TO -203
273 274 LOCATE ON OR NEAR MOTOR
℄ -244, 259 & 260 LOCATE APPROX. AS SHOWN
DRILL & TAP 3/8 -16 THRU -260 FOR -259
DRILL THRU -203 S.F. FOR -228 (2 PLS)
LOCATE APPROX AS SHOWN
LOCATOR POINTER 3/4 BELOW NET TRIM LINE
259
-271 & 272
-249
15
-257
258
257
-257
251 LENGTH TO BE SET ON ASSY
249
-231 (REF VIEW BB)
-205
DRILL S.F. FOR -253 PIN ASSY
℄ -253 ASSY
-245
SCREW & DOWEL AS REQ'D
-250
SCREW & DOWEL AS REQ'D.
SHIM AS REQ'D. ON ASSY
-20 SHT 1
VIEW D D
1/2 SCALE
OPTIONAL TO PROVIDE ANGLE OUTRIGGERS TO STAB. TRACK ASS'Y.
DR. 1/4 DIA CLEARANCE HOLE THRU -268 FOR -269 (TYP 2 PLS)
269
1/16 X 45° CHAM
SAW WIDTH
268

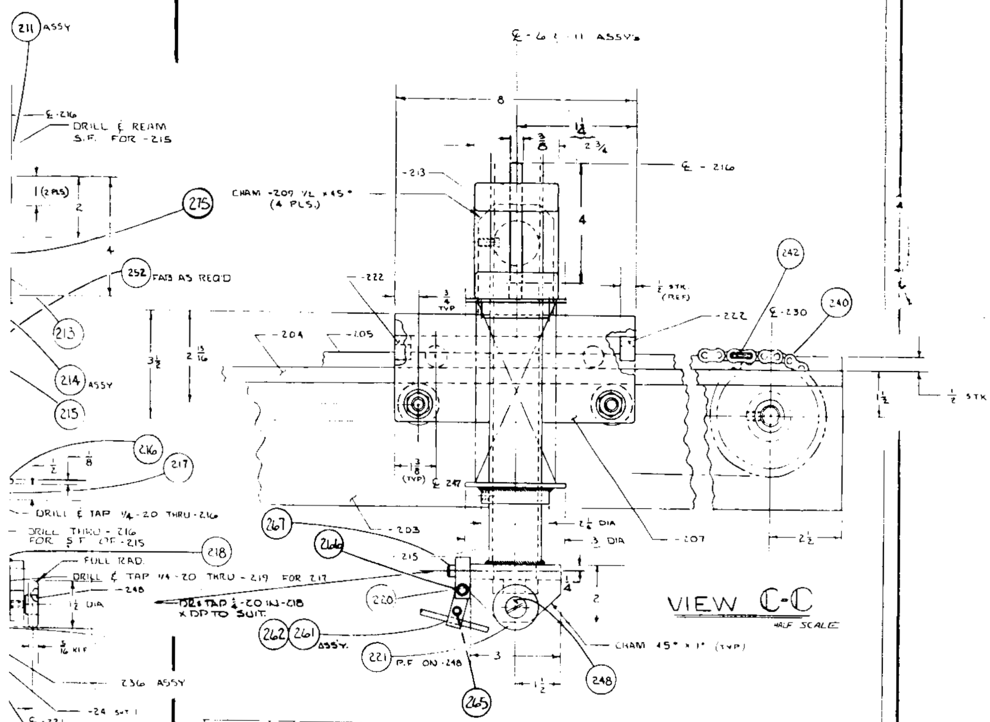
#2

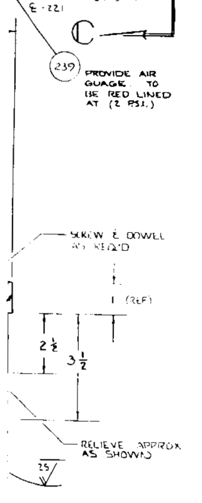


SCREW & DOWEL TO -208 AS REQ'D (REF. VIEWS BB & C-C)
LOCATE POINTER 6" BELOW ℄
DRILL FOR COTTER PINS SIMILAR TO -228
SIDE VIEW
1/4 SCALE
DRILL THRU -209 S.F. FOR -212 (2 PLS)
NOTCH AS REQ'D
FLAT IN SHAFT AS REQ'D FOR SET SCREW
DRILL 1 7/16 THRU -218
DRILL 3/4 THRU -219
SCREW & DOWEL AS REQ'D (2 PLS)
VIEW BB
1/2 SCALE
SHOWN WITH SKATE
GUIDE DETAIL (2 REQ'D)
1/2 SCALE
VIEW AA
1/2 SCALE
BRAZE
DR & RM. S.F. FOR -262 THRU -268
CLAMP
DR CLEARANCE HOLE THRU NEAR SIDE OF -263 & THRU -264 DR & TAP 1/4-20 THRU FAR SIDE FOR -266
FULL RAD.
DR & RM S.F. FOR -262 THRU -264
S.F. FOR -264
DR CLEARANCE NEAR SIDE FOR -265 & DR & TAP 10-32 FAR SIDE FOR -265.
SAW WIDTH
GUIDE ASSY.
℄ SYM.
CHILL BAR ASSY
FULL SCALE
REF VIEW DD, SHT 1 & VIEW BB, SHT 2.
#3
2

-18 THR'D TO
MATCH BAC 63K-208
WIRE FEED UNIT

1. 201 SUGGESTED SOURCE "RYERSON STL." CAT "57-58, PAGE 139.
2. 202 OPTIONAL 2 PC. CONSTRUCTION AS SHOWN.
3. 203 CONTOUR PER
4. 204 MAKE FROM
5. 205 SUGGESTED SOURCE "BOSTON GEAR" CAT # 58 PAGES 149, 145, 148, 171, 173, 622 & 728.
6. 206 SUGGESTED SOURCE "McGILL" BEARING HANDBOOK M-62, PAGES 8, 10 & 16
7. 207 SUGGESTED SOURCE "ZERO-MAX" CAT # 265 PAGE 9
8. 208 3 PC CONSTRUCTION OPTIONAL





ASSY USED ON	DETAIL NO	QUANTITY	NAME OF DETAIL	ZONE	MATERIAL	STOCK SIZE
	260	2	BACKING PLATE		HRS	½ × 1 × 4⅛
	259	1	THUMB SCREW			UT 7113-640
256	258	1	PLATE (END)		HRS	½ × 8 × 8⅛
256	257	3	PLATE (TOP) & (SIDES)		HRS	½ × 8 × 15⅛
	256	1	MOTOR BASE ASSY			
253	255	1	HANDLE		CRS ROUND	¼ DIA × 2⅛ LONG
253	254	1	LOCATING PIN		DRILL ROD	½ DIA × 1¾ LONG
	253	1	PIN ASSY			
	252	1	SPRING		MUSIC WIRE	.051 × LENGTH TO SUIT
	251	1	SHAFT		DRILL ROD	5/8 DIA ×
	250	1	MOTOR & GEAR HEAD	207		# JK3-W4-M3
	249	1	COUPLING ONE END 5/8, ONE END ¾	205		# FCBB15
214	248	2	CAM FOLLOWER	206		# CF 5/8
232	247	4	SHAFT MOUNTING BEARING	206		# CYR 3/4
206	246	4	SEALED CAM FOLLOWER	206		# CF -1⅜-S
	245	4	COLLAR	205		# SC-62
	244	4	SPROCKET	205		# KSU-9-1
	243	2	SPROCKET	205		# KSUC-24-C
	242	AS REQ'D	CONNECTING LINK	205		# 41 SP-CL
	241	2	CHAIN ATTACHMENT	205		# 41 K-1
	240	1	CHAIN (ROLLER)	205	ASA STANDARD	# 41 LENGTH TO SUIT
	239	1	BLADDER		RUBBER	3/8 × 2¼ × LENGTH TO SUIT
236	238	1	FLEX STRIP		SILICONE	TO SUIT
236	237	600 PER FT	CHILL BAR SEGMENT			204
	236	1	CHILL BAR ASSY			LENGTH TO SUIT
232	235	4	SPRING		SPRING STL	.042 × 1⅛ × 3
232	234	8	COLLAR		HRS	½ × ½ × 5/8
232	233	4	SHAFT		DRILL ROD	¼ DIA. × 1⅜ LONG.
206	232	4	ROLLER ASSY			
	231	4	BUSHING		BRONZE HOLLOW ASARCON	1⅛ O.D. × ½ I.D. × 5/8
	230	1	SHAFT		DRILL ROD	5/8 DIA × 4 ⅞ LONG
	229	2	SHAFT		DRILL ROD	½ DIA × 5 5/8 LONG
	228	2	SHAFT		DRILL ROD	3/8 DIA × 5 ¾ LONG
224	227	2	SHAFT		DRILL ROD	½ DIA. × 2 3/8 LONG
223	226	4	IDLER SUPPORT		HRS	½ × 2 × 2⅛
223	225	2	PLATE		HRS	¼ × 2½ × 4⅜
223	224	2	PIVOT		CRS ROUND	3/4 DIA × 4⅛ LONG
	223	2	IDLER ASSY.			
206	222	2	GUIDE		O2 TOOL STL.	½ × 1 × 2⅛ Rwc 60-62
214	221	2	ROLLER		CRS	AS REQ'D
214	220	2	ROLLER SUPPORT		HRS	½ × 2 × 3⅛
214	219	1	TIP CLAMP		HRS ROUND	1½ × 5/8 LONG
214	218	1	PLATE		HRS	½ × 3 × 3⅛
214	217	3	SET SCREW		SOC. HD.	¼-20 × 3/8
214	216	3	COLLAR	202	HRS ROUND	3" DIA × 3/4 LONG
214	215	1	SEAMLESS MECH. TUBING	201	STL	1 3/4 O.D. × .095 WALL × 16 LONG
	214	1	WELD HEAD ASSY.			
211	213	1	YOKE		HRS TANK PLATE	3 × 4 × 4
211	212	1	ADJUSTMENT BAR		CRS ROUND	1½ × 10⅛ LONG
	211	1	YOKE ASSY			
206	210	2	SCREW		SET, SOCKET HD	¼-20 × 1 LONG
206	209	2	UP RIGHTS		HRS	1 × 2½ × 3 ¼
206	208	1	PLATFORM		HRS	3/4 × 8 × 8 5/8
206	207	2	ROLLER SUPPORT		HRS	3/4 × 4 × 8⅛
	206	1	SKATE ASSY.			
203	205	2	GUIDE BAR		CRS	½ × 3/4 × TO SUIT
203	204	1	TRACK		CRS	½ × 8 × TO SUIT
203	203	2	BRACE (TRACK)		HRS	½ × TO SUIT
	202	1	SUPPORT ARM		HRS	1 × 5 × 12 ⅛
	201	1	LOCATING PIN		CRS. ROUND	3 DIA × 3 5/8

TOOLING CHANGE ORDER			
LTR	NUMBER	DATE	

DRAWING NUMBER | SHEET | ARCH OR ECN NO | USED ON
LAST PRODUCTION DRAWING CHANGE

SCALE NOTED
ALL DIMENSIONS IN INCHES
EXCEPT AS NOTED
TOLERANCE
FRACTIONAL ±
DECIMAL ±
ANGULAR ±
MACHINE FINISH SEE TDM
FLOOR AREA 10 FT SQ
APPROX WT
PROD CHG NO
WORK ORDER
TDE OR SH

SHOP	CONCURRENCE	DATE
	NAME	DATE
DESIGN BY		
DETAIL BY	MATTINGLY	
CHECK BY		
APPROVED		
APPROVED		

ZONE | MATERIAL | STOCK SIZE
COLOR OF PROTECTIVE FINISH
MODEL EXPERIMENTAL | SECTION
DRAWING SHEET SIZE

TOOL DRAWING
THE BOEING COMPANY
WICHITA DIVISION · WICHITA 1 KANSAS

PLASTER MODEL COMPOSITE BULKHEAD

1XPM-MRST-SK717B
SHEET 2

FIG 3

MFG DEVELOPMENT

ISSUE
SHEET
ATTACHMENTS
DEV | SO

#4

TENSILE TEST DATA

SPEC NO.	WIDTH	THICK	AREA	UTS	YLD	UTS PSI	YLD PSI	ELONG	HARD
1	.5038	[illegible]	.0425	[illegible]	[illegible]	[illegible]	48,250	[illegible]	
1A	.5045	[illegible]	.0425	2675	2010	62,940	47,290	8.5%	
2	[illegible]	.0850	.0435	2780	2065	[illegible]	47,470	10.5%	
2A	.5051	.0860	.0434	2780	[illegible]	64,050	47,250	9%	
3	[illegible]	.0870	.0439	2810	2080	64,010	[illegible]	9.5%	
3A	.5055	.0870	.0440	2850	[illegible]	64,770	47,730	9%	

[illegible] R.T.

AVE TEST VALUES — 2219 T87 MIN VALUES

UTS PSI =	63790	63000
YLD PSI =	47595	50,000
ELONGATION =	8-10.5%	5%

UN FORM 297

Figure 4

NAS 8-11900

INS 438 W 4-13

THE BOEING COMPANY
MILITARY AIRPLANE DIVISION - WICHITA BRANCH
WICHITA, KANSAS, 67210

QUALITY CONTROL LABORATORY REPORT Q 49357

Date 10-19-65 Submitted by 3260 - G. Beard (DEPT. NO. / INSP. OR SHOP SUPV.) Prepared by 3070 - Ray Cox 5880 (DEPT. NO. / NAME / PHONE)

Description: R.N. Part No. MR&T-SK717D-1 P.O. Quantity Rec'd

Material 2219-T37 Aluminum Alloy Vendor

No. of Samples 1 No. of Pieces 1 Spec. No. Copies to 3260 - GBeard ~~1cc~~ (DEPT. NO. / NAME)
3070 - RCox 1cc
USAF - Chief,Q.C. 1cc

Information Requested Check grain structure to determine cause of orange peel.

DZ:mm

One part, MR&T-SK717D-1, was submitted to the Quality Control Laboratory for the purpose of determining the cause of the orange peel. The material used in making the part was 2219-T37 aluminum alloy. The material was re-solution heat treated and stretch formed in the (W) condition. After forming the part was chem milled on one side.

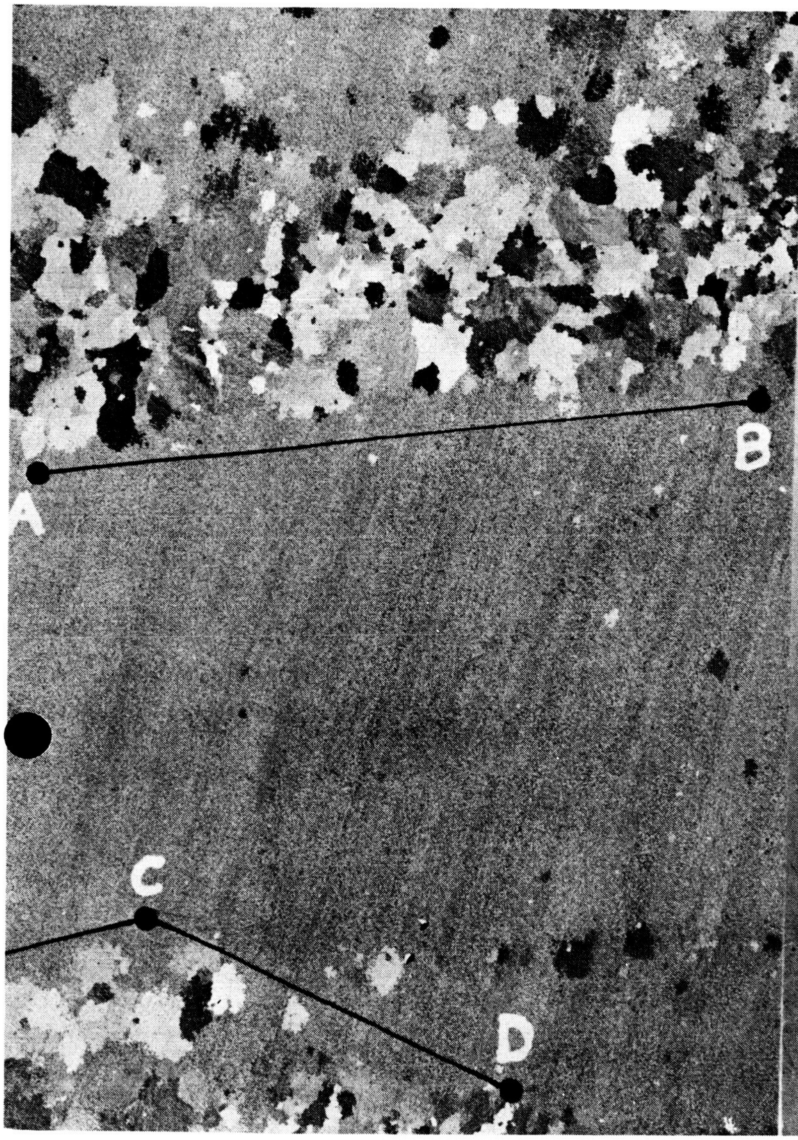
As shown in Figures 1 and 2 the orange peel produced during the forming operation was a result of the large grain in the part. As can be noted the orange peel area was in the area of large grain size. The small grain size area had no orange peel produced as a result of the forming operation. The large grains were produced as a result of critical deformation and re-solution heat treatment. Critical deformation or critical strain can be defined as the percentage of strain at which, or immediately higher than which, large grain growth occurs during heating. The critical strain is between 6 and 12% depending on the alloy, original grain size, heating rate, time at temperature, etc. It should be noted that 2219-T37 implies that the material has been cold reduced about 8% after solution heat treatment. This cold reduction was the source of the critical deformation. The best way to eliminate non-uniform grain size in the finish product is to purchase a fine grain T4 or annealed material.

The part was destroyed in testing and the remmants returned to 3260 - G. Beard.

- Continued -

Prepared by ______ Approved by ______

Figure 5



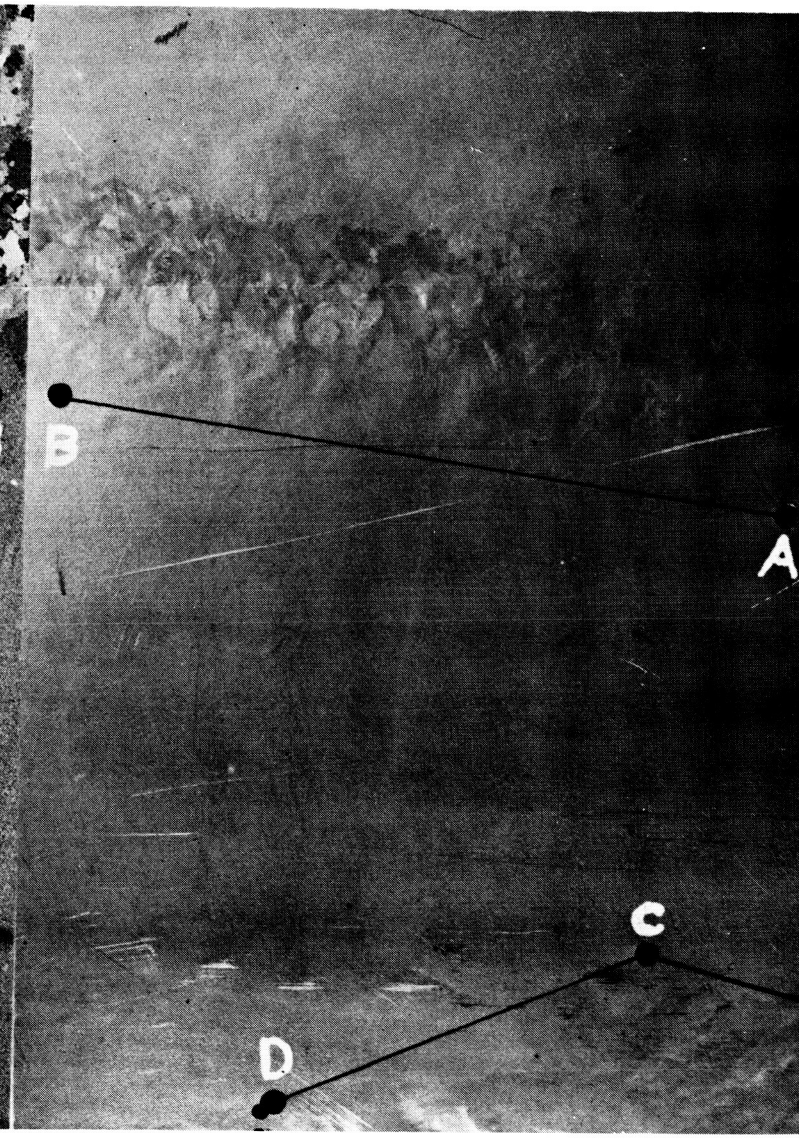


PHOTO NO. 820 MILLED SIDE

Figure 1 Mag. 1X

PHOTO NO. 821 NON-MILLED SIDE

Figure 2 Mag. 1X

The above photographs reveal the large grains on the chem-milled side of the part and the orange peel surface on the non-milled side of the plate. Holes were drilled through the plate at A, B, C, and D as index points.

Prepared by D. Zabel

Approved by O.R. Borngesser

INS 438 W R13

THE BOEING COMPANY
MILITARY AIRPLANE DIVISION WICHITA BRANCH
WICHITA, KANSAS, 67210

QUALITY CONTROL LABORATORY REPORT Q 50053

Date 10-28-65 Submitted by 3070 - Ray Cox (DEPT. NO. / INSP. OR SHOP SUPV.) Prepared by 2260 - Heckathorn 5880 (DEPT. NO. / NAME / PHONE)

Description: R.N. ____ Part No. MRST-SK717B-3 1st Stage P.O. ____ Quantity Rec'd 1

Material ____ Vendor ____

No. of Samples ____ No. of Pieces ____ Spec. No. BAC 5450 Copies to 3070 - RCox ~~2cc~~ (DEPT. NO. / NAME)
USAF - Chief,Q.C. 1cc

Information Requested Pull all lap shear samples.

MC:mm

The lap shear and climbing peel tests on BMS 5-17 adhesive were conducted in accordance with the requirements of Specification BMS 5-17. The following data were obtained:

LAP SHEAR TENSILE				CLIMBING PEEL	
Panel #1		Panel #2			Peel Torque
Specimen	Load (Lbs.)	Specimen	Load (Lbs.)	Specimen	(In. Lbs. Per 3 In.)
1	920*	1	980	1	36
2	850	2	970	2	37
3	840*	3	920*	3	35
4	850	4	890	4	36
5	930*	5	890	5	36
				6	36
Average (PSI)	1760	Average (PSI)	1860		
				Average	36

*These specimens slipped in the jaws and were cooled and re-cycled for another full ten minute cycle.

The specimens were destroyed and the remnants returned to Dept. 3070.

Prepared by Max Collier Approved by O.R. Borngesser

Figure 6

INS 438 W R13

THE BOEING COMPANY
MILITARY AIRPLANE DIVISION · WICHITA BRANCH
WICHITA, KANSAS, 67210

QUALITY CONTROL LABORATORY REPORT Q 50054

Date 10-28-65 Submitted by 3070 - Ray Cox (DEPT. NO. / INSP. OR SHOP SUPV.) Prepared by 3260 - Heckathorn 5880 (DEPT. NO. / NAME / PHONE)

Description: R.N. ______ Part No. MPST-SK717B-3 2nd Stage P.O. ______ Quantity Rec'd ______

Material ______ Vendor ______

No. of Samples ______ No. of Pieces ______ Spec. No. BAC 5450 Copies to 3070 - RCox 2cc (DEPT. NO. / NAME)
USAF - Chief, Q.C. 1cc

Information Requested Pull all lap shear samples.

MC:mm

The lap shear and climbing peel tests on BMS 5-17 adhesive were conducted in accordance with the requirements of Specification BMS 5-17. The following data were obtained:

LAP SHEAR TENSILE

Panel #1 Specimen	Panel #1 Load (Lbs.)	Panel #2 Specimen	Panel #2 Load (Lbs.)
1	950	1	990
2	850	2	940
3	870	3	940*
4	890	4	960
5	930	5	930
Average (PSI)	1800	Average (PSI)	1900

CLIMBING PEEL

Specimen	Peel Torque (In. Lbs. Per 3 In.)
1	51
2	46
3	50
4	45
5	49
6	49
Average	48

*These specimens slipped in the jaws and were cooled and re-cycled for another full ten minute cycle.

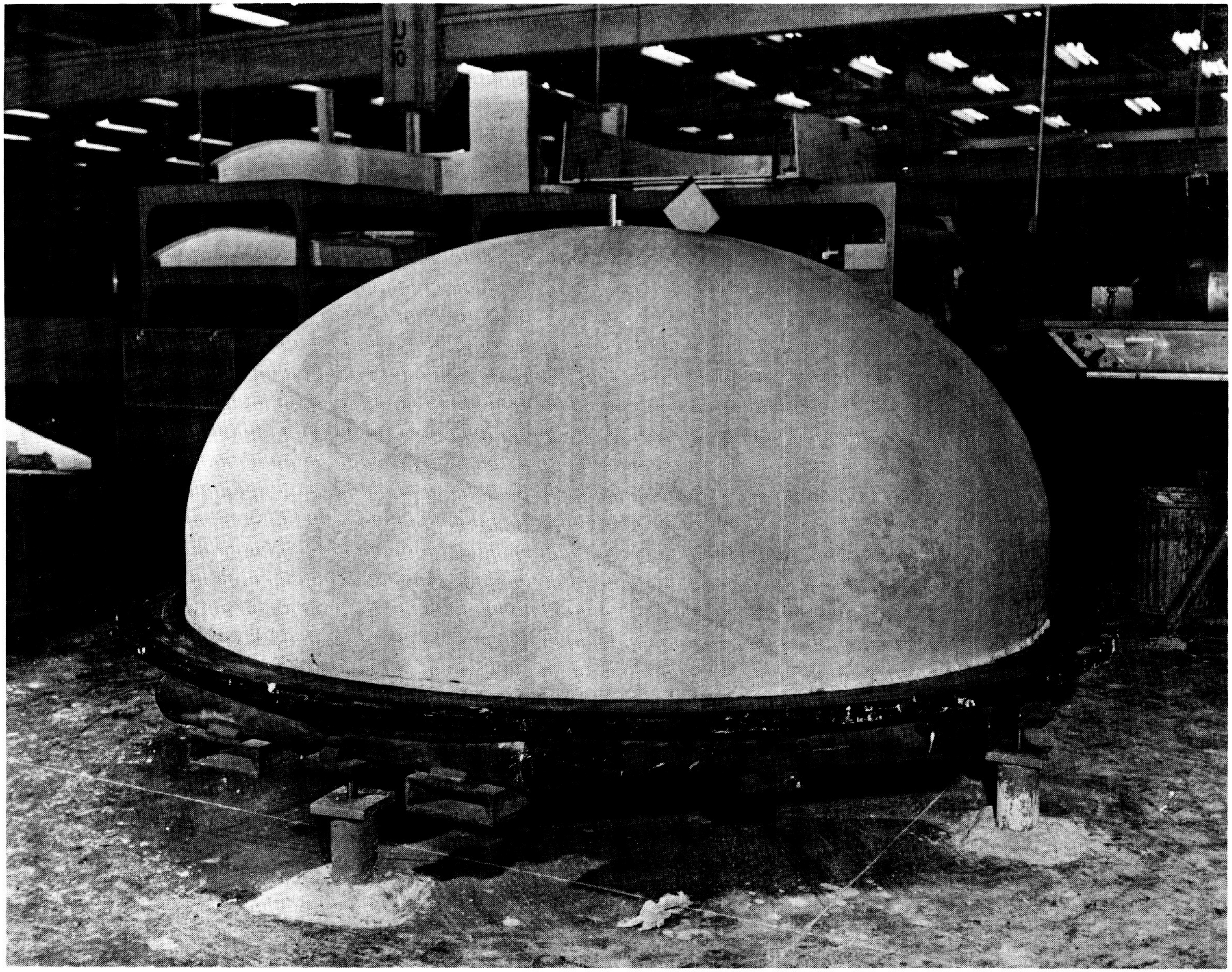
The specimens were destroyed and the remnants returned to Dept. 3070.

Prepared by Max Collier Approved by O.R. Borngesser

Figure 7

PROJ. 78.57 PLASTER MASTER UNDER STRUCTURE - TYPICAL BOTH PMs FIG. 8

NAS 8-11900 BW-172446



PROJ. 78.57
NAS 8-11900

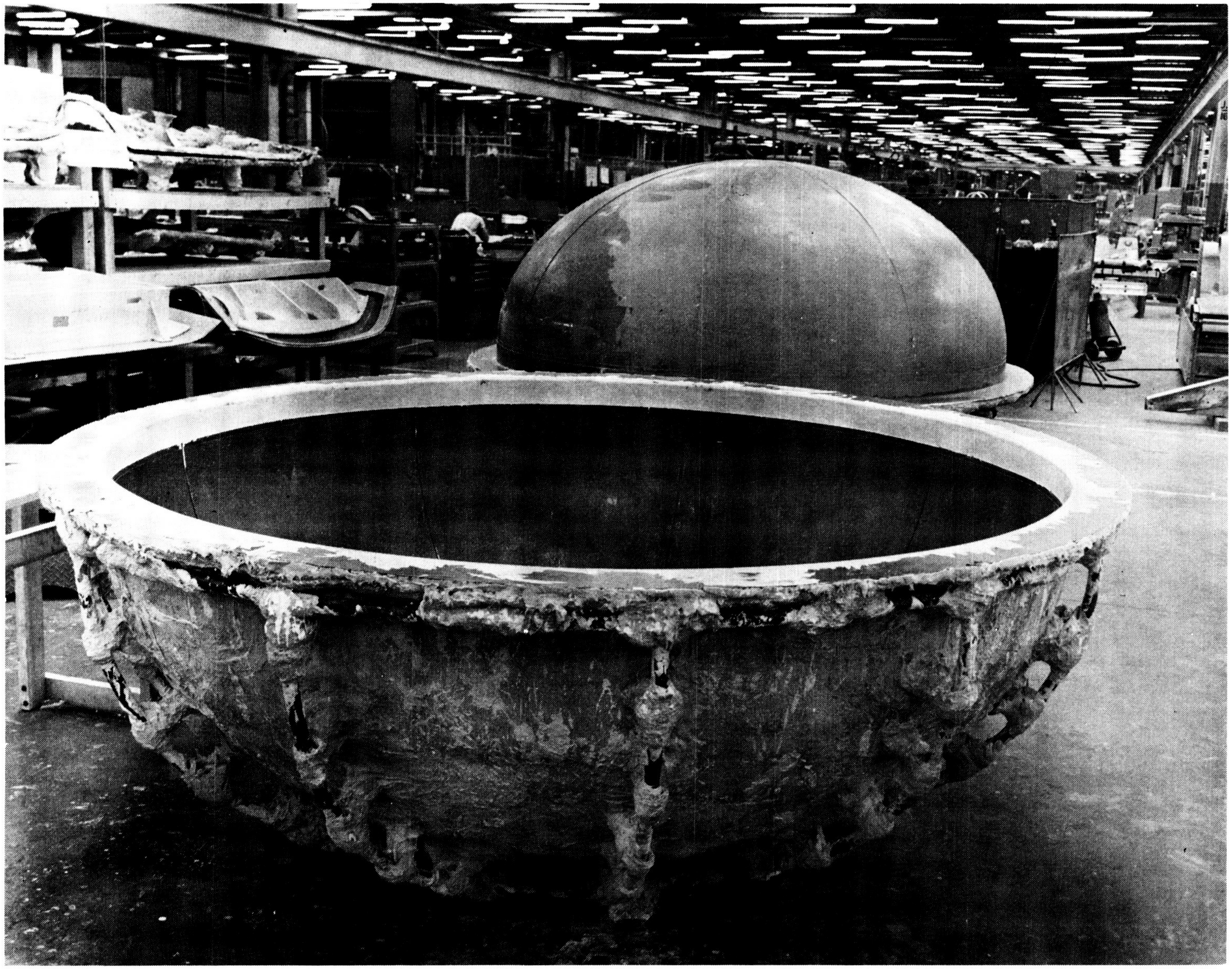
PLASTER MASTER - CONCAVE FORMING & AGING TOOL INNER SURFACE PRIOR TO ADDING WELD LAND CLEARANCE SPLINES

FIG. 9
BW-172447

PROJ. 78.57
NAS 8-11900

REMOVAL OF CONCAVE FORMING AND AGING TOOL TRANSFER SPLASH FROM PLASTER MASTER 1XPM-MR&T-SK717B

FIG. 10
BW-172448



PROJ. 78.57
NAS 8-11900

CONCAVE FORMING & AGING TOOL TRANSFER SPLASHES
NO. 1 & NO. 2

FIG. 11
BW-172449

INS 438 W R1

THE BOEING COMPANY
MILITARY AIRPLANE DIVISION - WICHITA BRANCH
WICHITA, KANSAS. 67210

QUALITY CONTROL LABORATORY REPORT Q 48359A

Date 10-7-65 Submitted by 3070 - Ray Cox (DEPT. NO. / INSP OR SHOP SUPV.) Prepared by 4810 - F. Liscum (DEPT. NO. / NAME / PHONE)

Description: R.N. ______ Part No. MRNT-SK717B P.O. ______ Quantity Rec'd ______

Material Unbonded Skin of Dome Vendor ______

No. of Samples ______ No. of Pieces ______ Spec. No. ______ Copies to 3070 - RCox ~~1cc~~ (DEPT. NO. / NAME)

3070 - Buchanan 1cc

Information Requested Make X-Ray Inspection of Welds. USAF - Chief, Q.C. 1cc

FL:fm

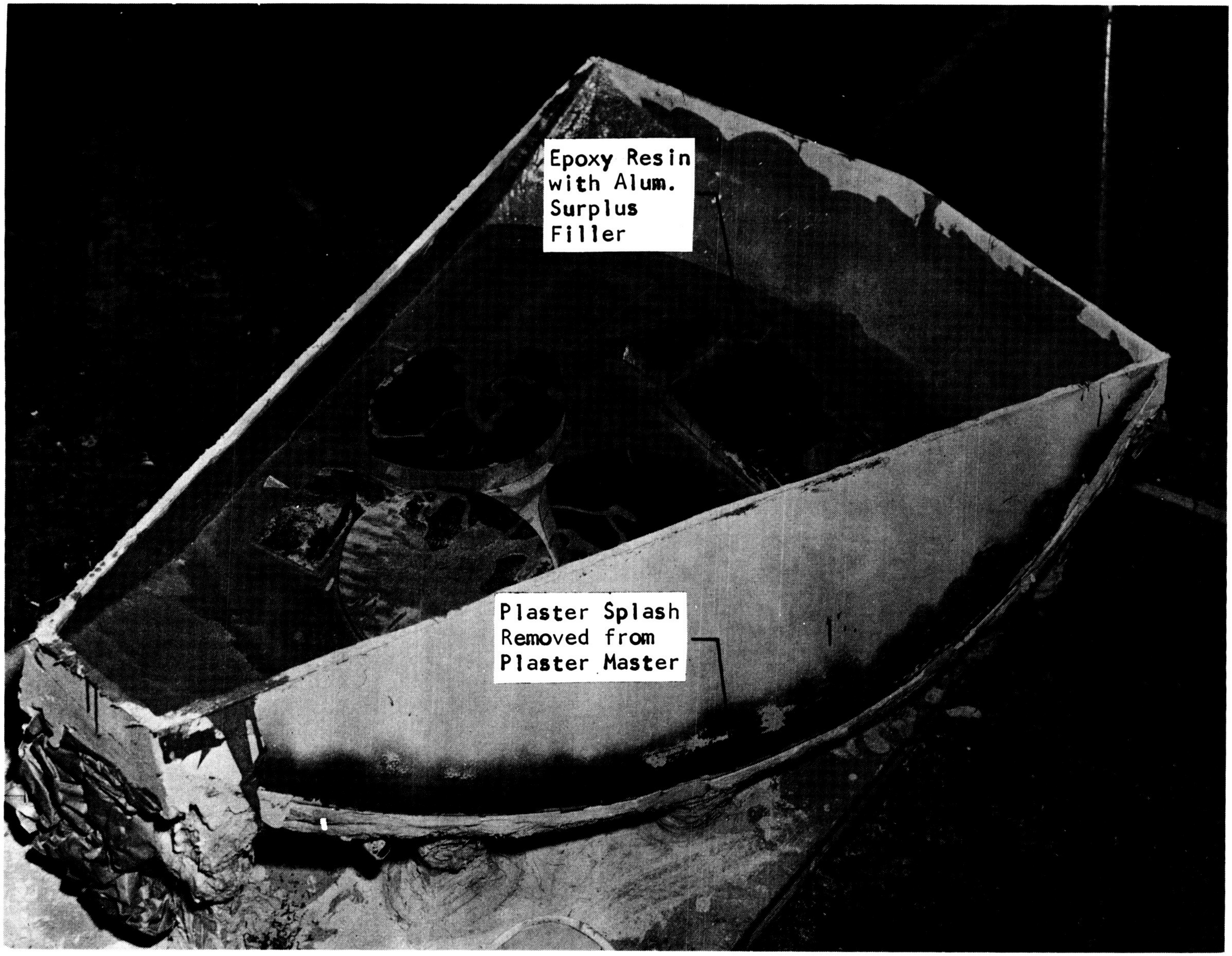
BUTT WELDS

One unbonded aluminum dome skin part number MRNT-SK717B, was submitted to the Quality Control Laboratory for radiographic examination of butt welds.

Radiographic examination showed that 75 percent of the length of all welds contained linear porosity and lack of penetration. None of these defects appeared to be deeper than 30 percent of the weld thickness. The welds will not meet radiographic quality requirements of any Aero Space or Commercial Code that is available to the Laboratory.

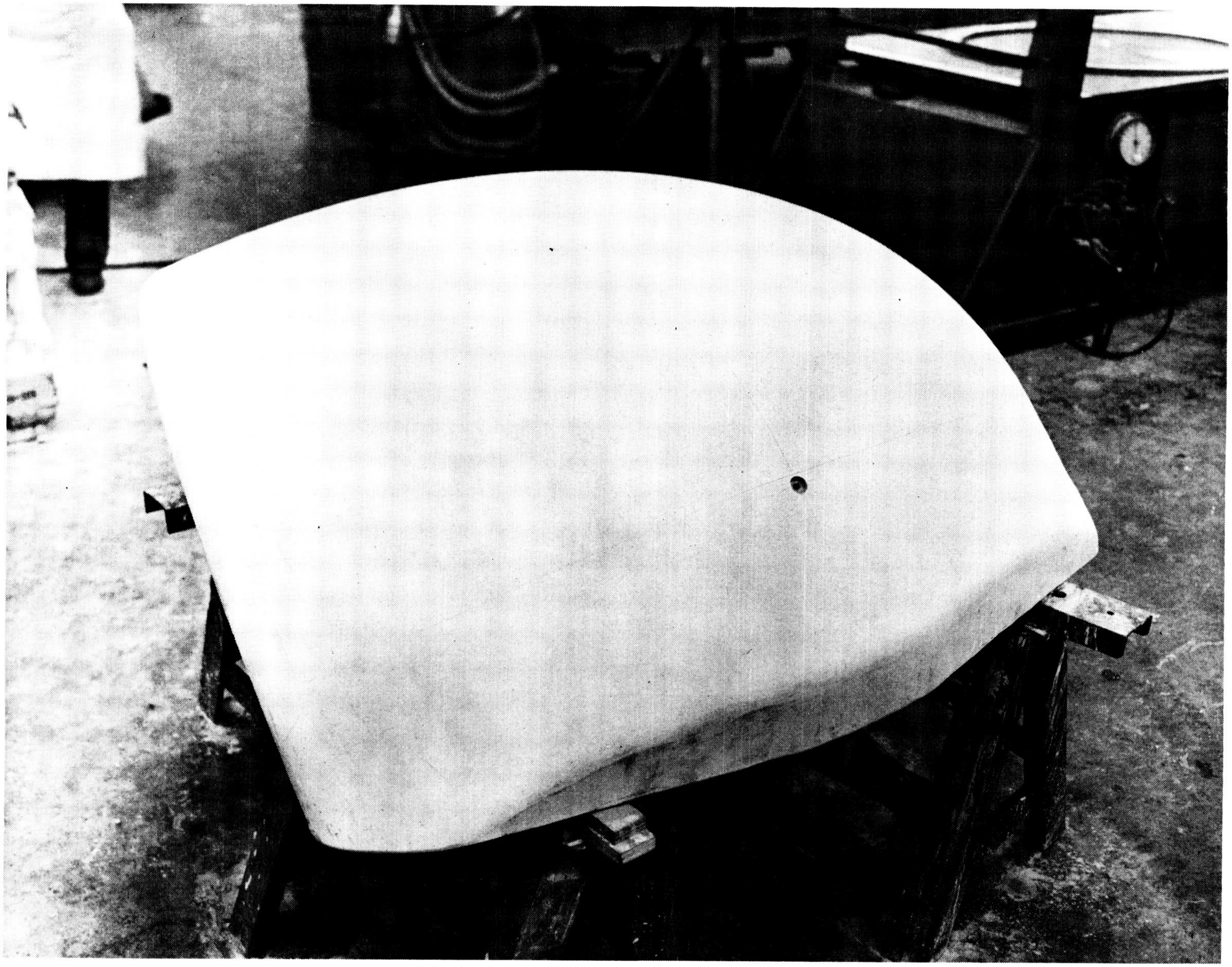
This report is written to supplement and clarify Q48359.

Prepared by F. C. Liscum Approved by O. R. Borngesser



PROJ. 78.57 INTERMEDIATE STEP IN FABRICATION - XSTFB-MR&T-SK717B FIG. 13

NAS 8-11900 BW-172450



PROJ. 78.57

NAS 8-11900

STRETCH FORM TOOL - TYPICAL - BOTH INNER & OUTER SKIN TOOLS - 1XSTFB-MR&T-SK717B

FIG. 14

BW-172451

CONCAVE FORMING AND AGING TOOL

XBAJ-MR&T-SK717B

Material --

Glass Fiber Fabric - Hess Goldsmith "HG-63" Glass Cloth, .015" Thick or Equivalent

Epoxy Resin - Midcon M-500 100 Parts

Hardener - Midcon M-510 50 Parts

(Midcon Plastics Co., Wichita, Kansas)

Layup (8) Ply (approx. .12" thick) on Mold. Enclose in Vacuum Bag and evacuate to 20 inches H.G. Vacuum. Heat to 200°F. and hold for (3) Hours.

Repeat Operation until final thickness is obtained.

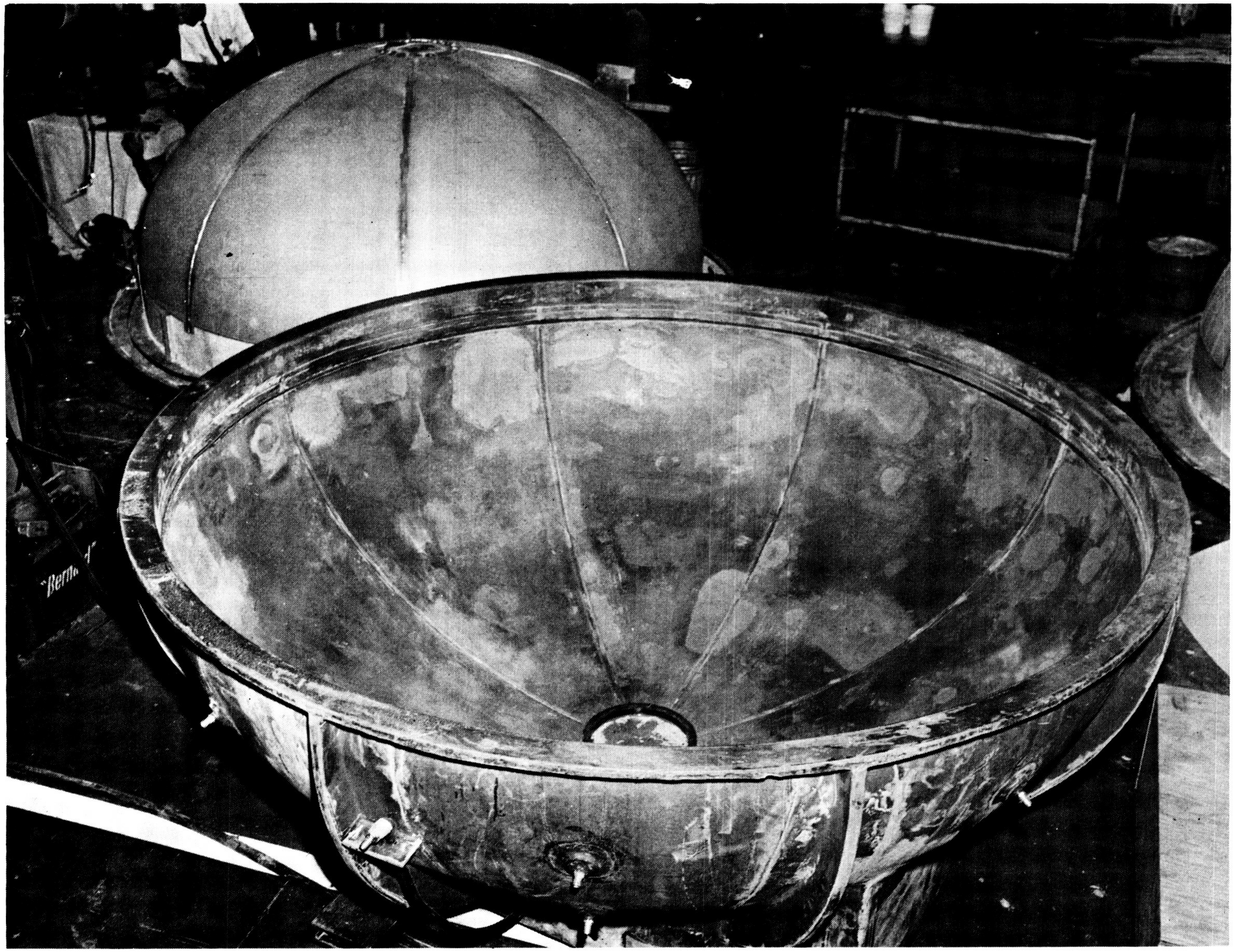
Final Cure Cycle for XBAJ, including last laminated fabric addition, to be:

3 Hours at 150°F.
3 Hours at 200°F.
3 Hours at 250°F.
3 Hours at 300°F.
3 Hours at 350°F.
8 Hours at 400°F.

Coefficient of Linear Expansion of the laminate after cure as noted above is 12.5×10^{-6} per in/in/°F. when heated to 344°F.

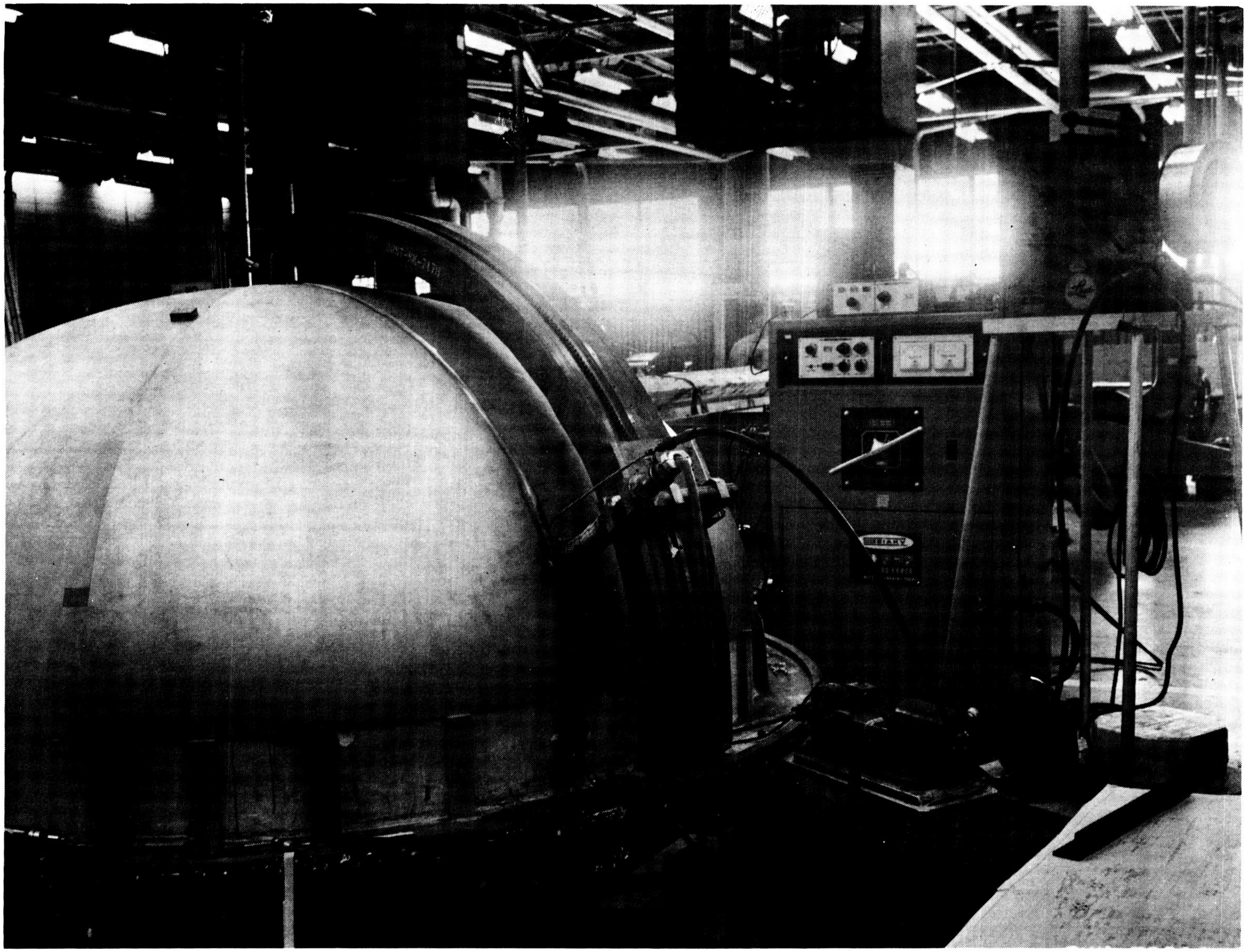
2219-T37 Aluminum Alloy coefficient was determined to be 12.0×10^{-6} per in/in/°F. when heated to 344°F.

Fig. 15 Concave Forming & Aging Tool XBAJ - MR&T - SK717B



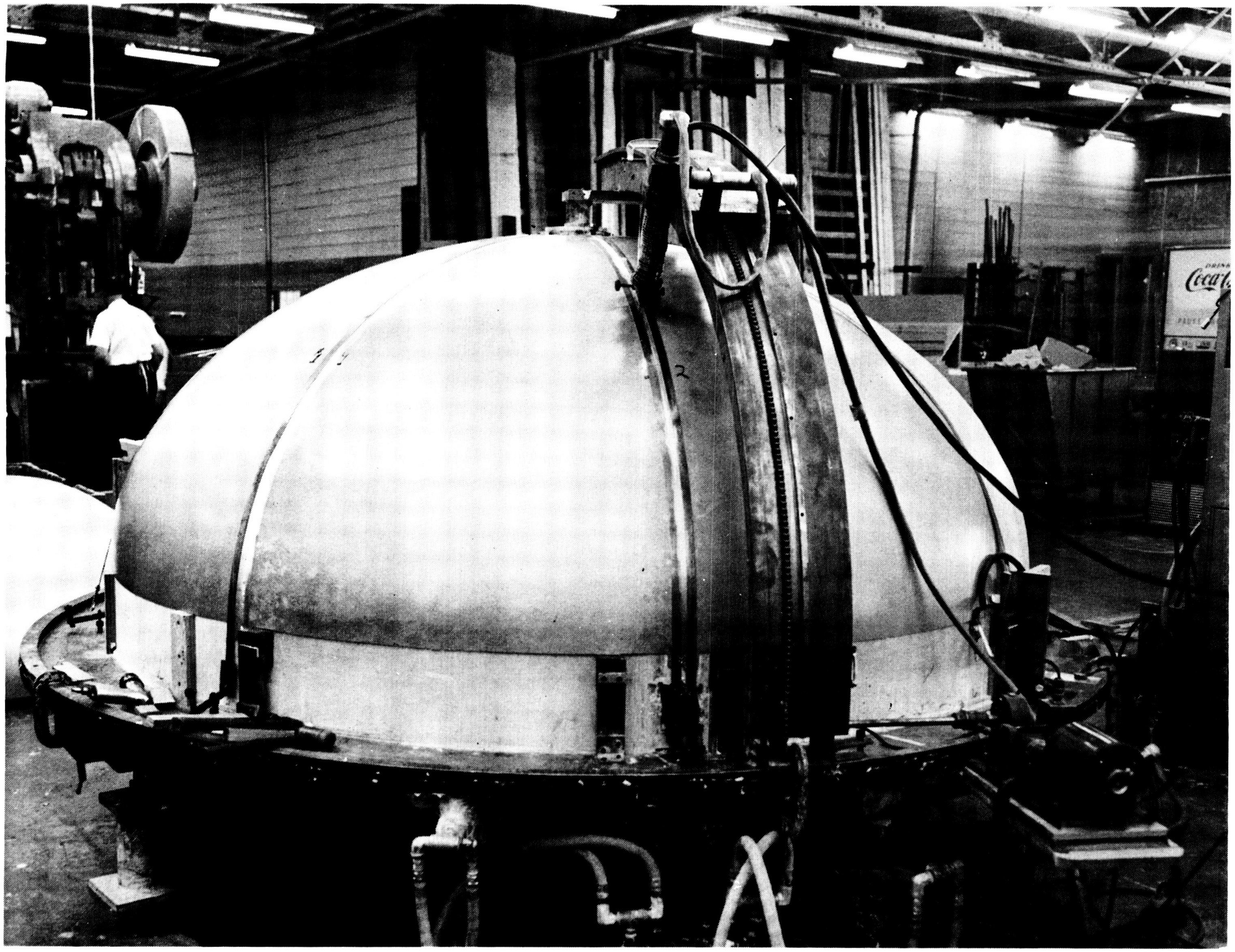
PROJ. 78.57 CONCAVE FORMING & AGING TOOL - XBAJ-MR&T-SK717B FIG. 16

NAS 8-11900 BW-172452



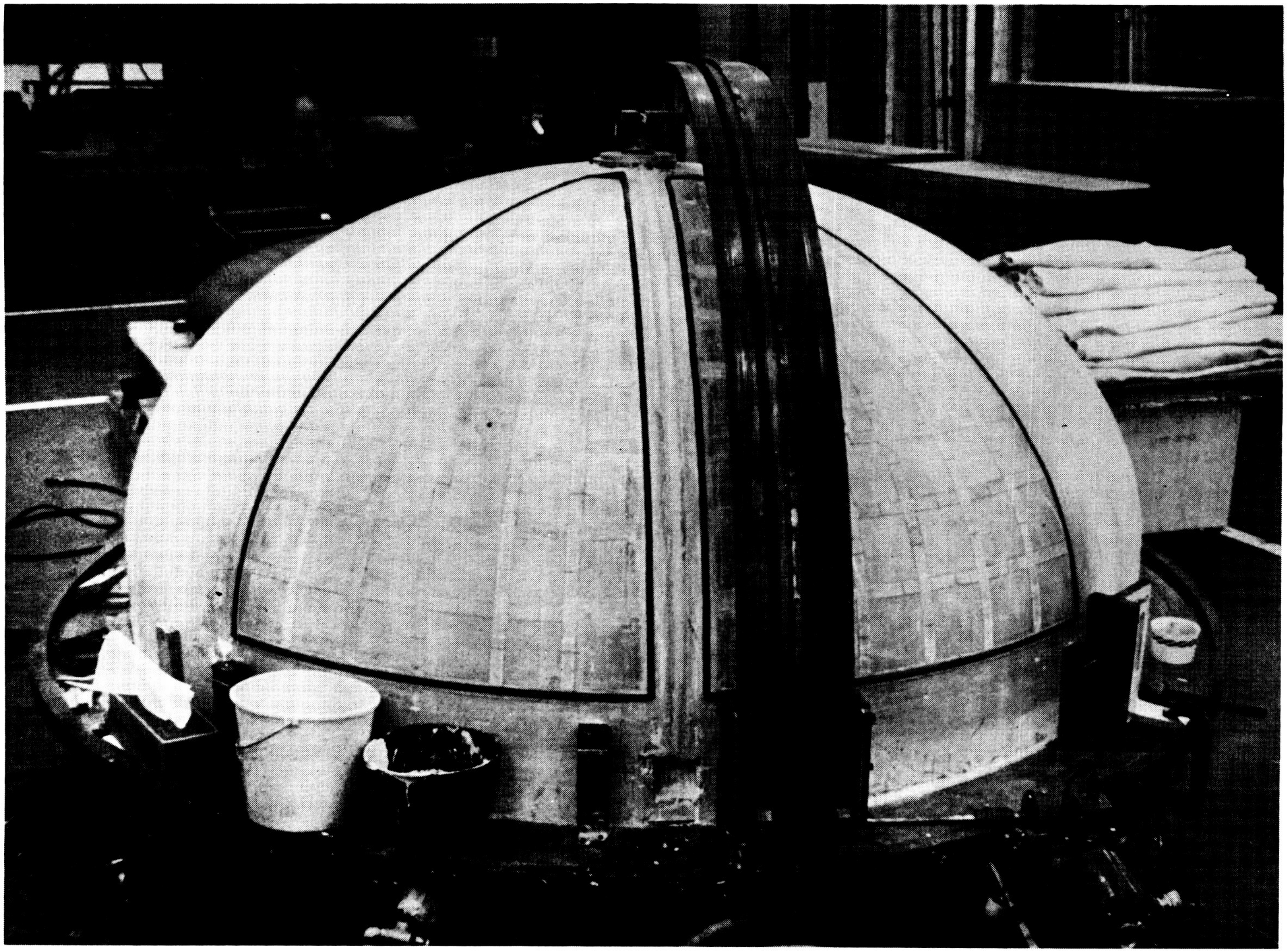
PROJ. 78.57 | PLASTER MASTER ADAPTED FOR WELDING - 1XPM-MR&T-SK717B | FIG. 17

NAS 8-11900 | BW-172453



PROJ. 78.57 — PLASTER MASTER ADAPTED FOR WELDING - 2XPM-MR&T-SK717B — FIG. 18

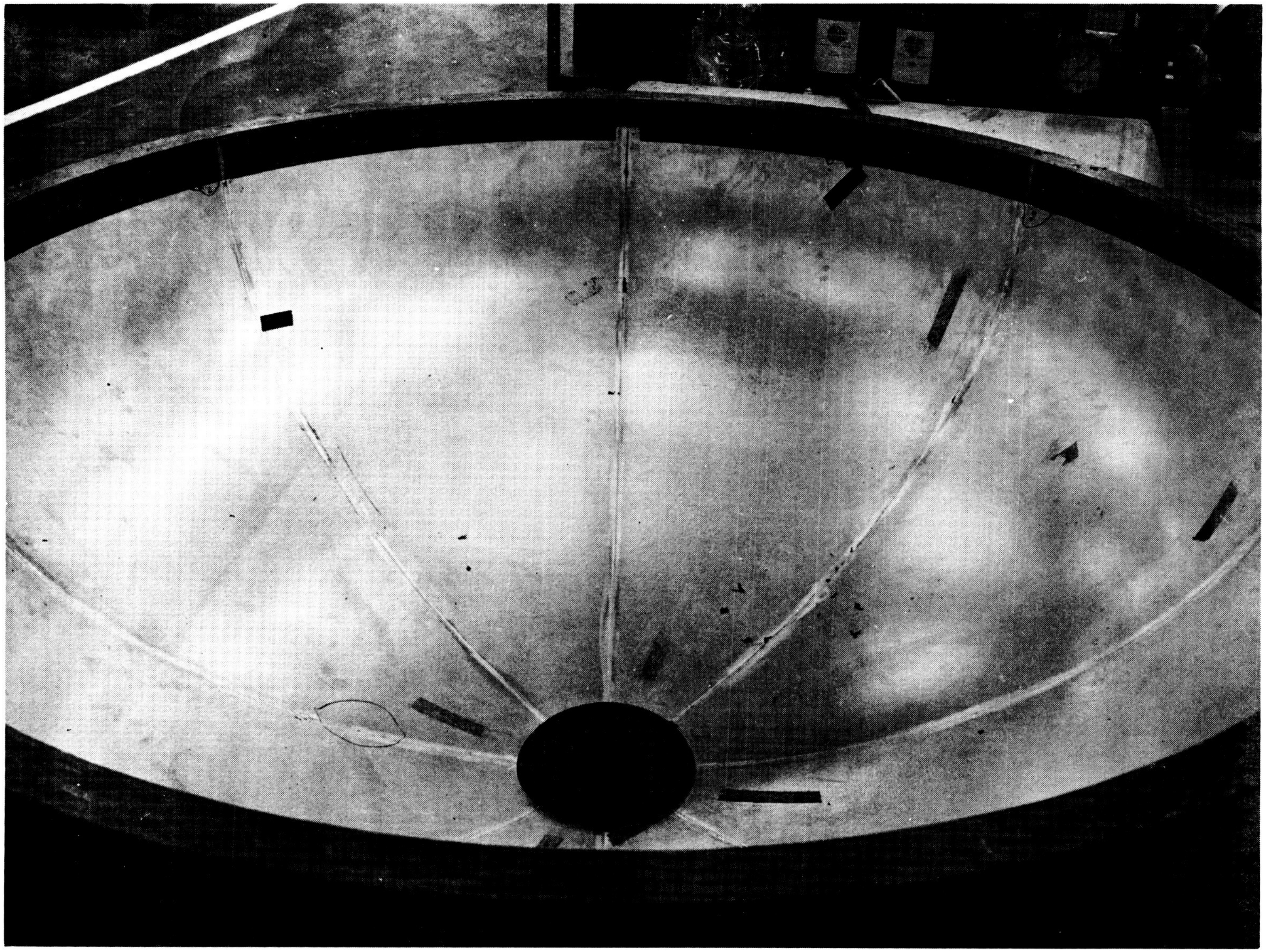
NAS 8-11900 — BW-172454



PROJ. 78.57
NAS 8-11900

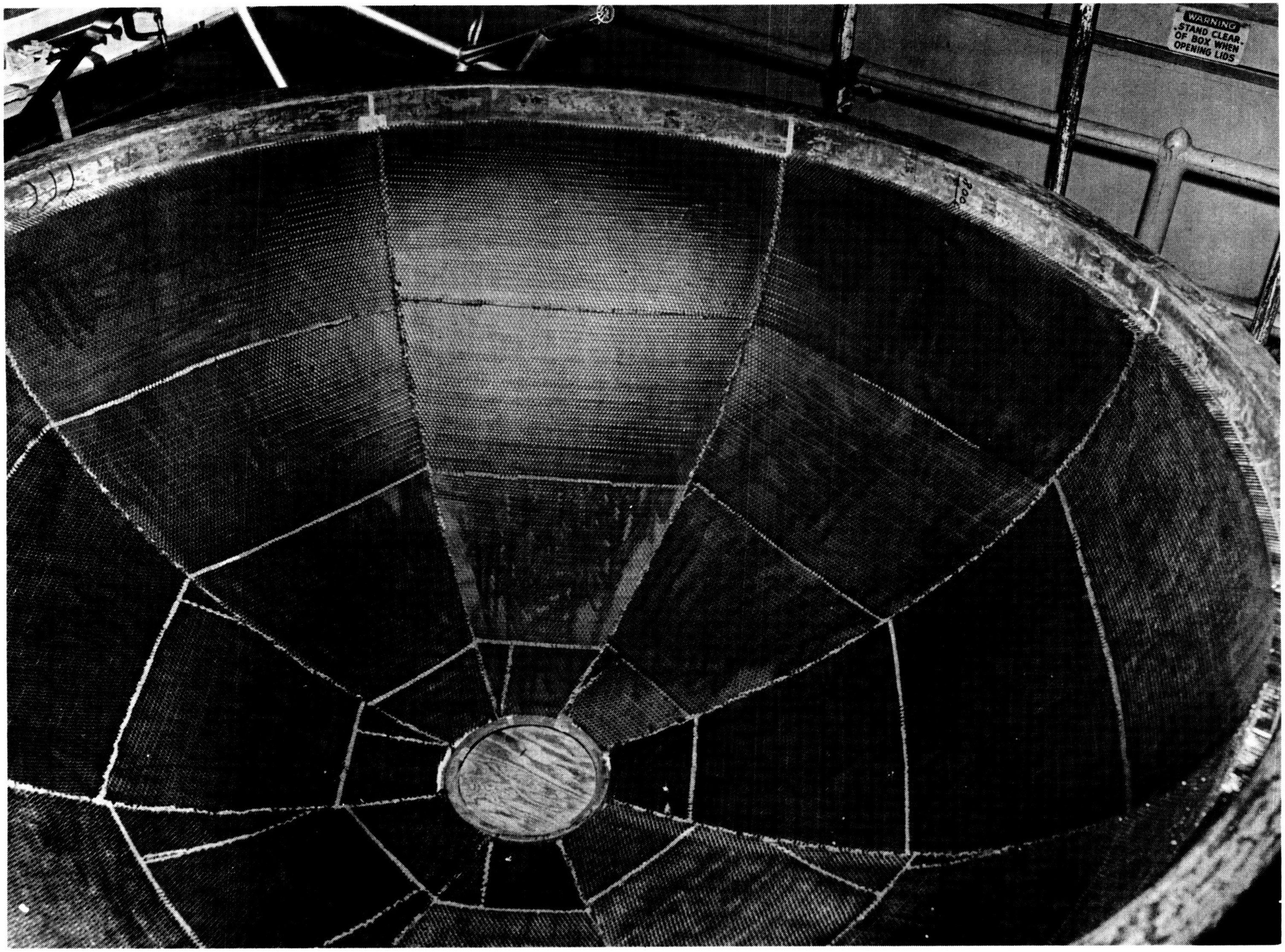
PLASTER MASTER WELD ADAPTATION SHOWING TYPICAL VACUUM GROOVE SEAL

FIG. 19
BW-172455



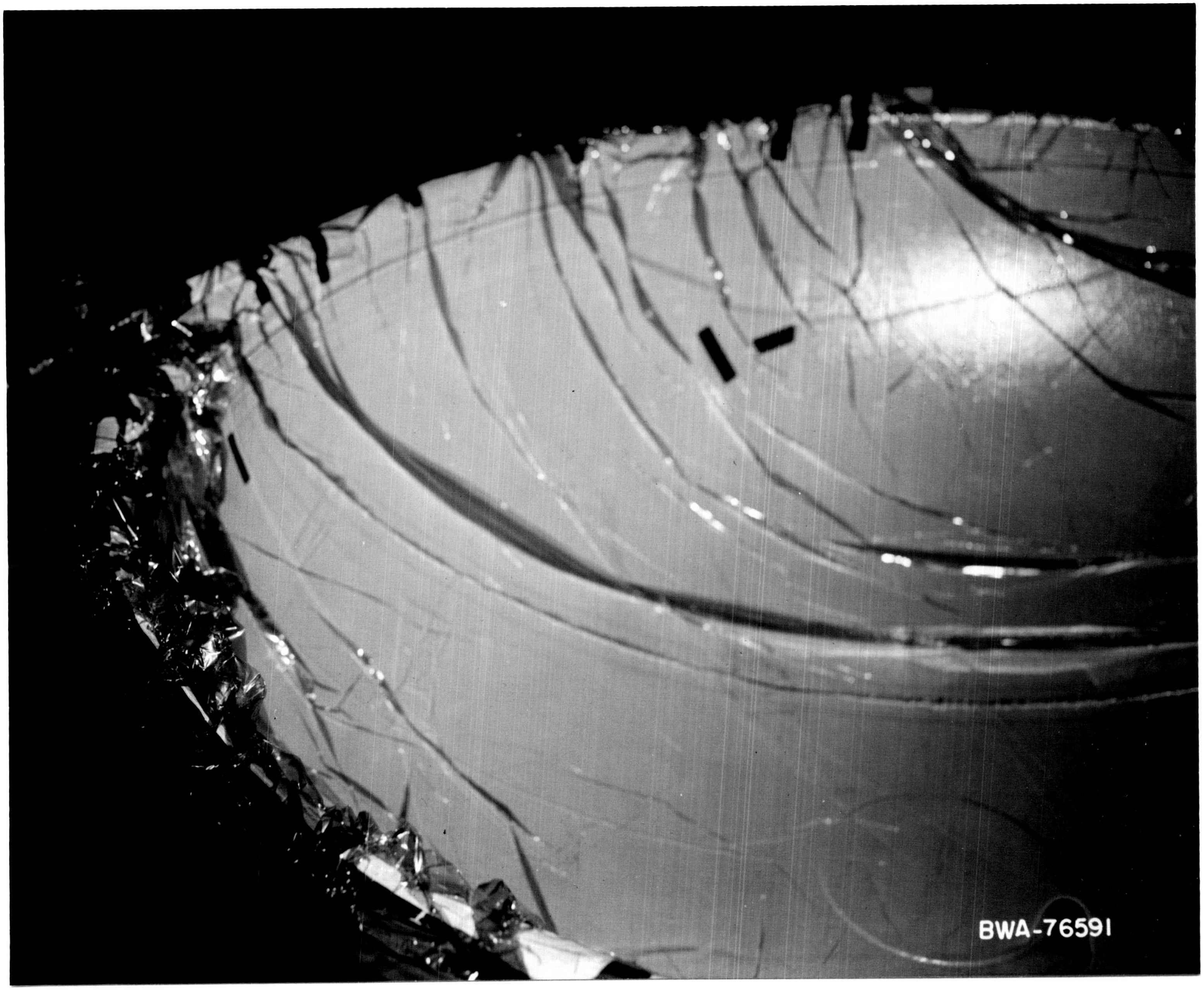
PROJ. 78.57 OUTER SKIN LOCATED IN CONCAVE FORMING & AGING TOOL AFTER AGE FORMING FIG. 20

NAS 8-11900 BW-172456



PROJ. 78.57 HRP CORE ADHESIVE BONDED TO THE OUTER SKIN FIG. 21

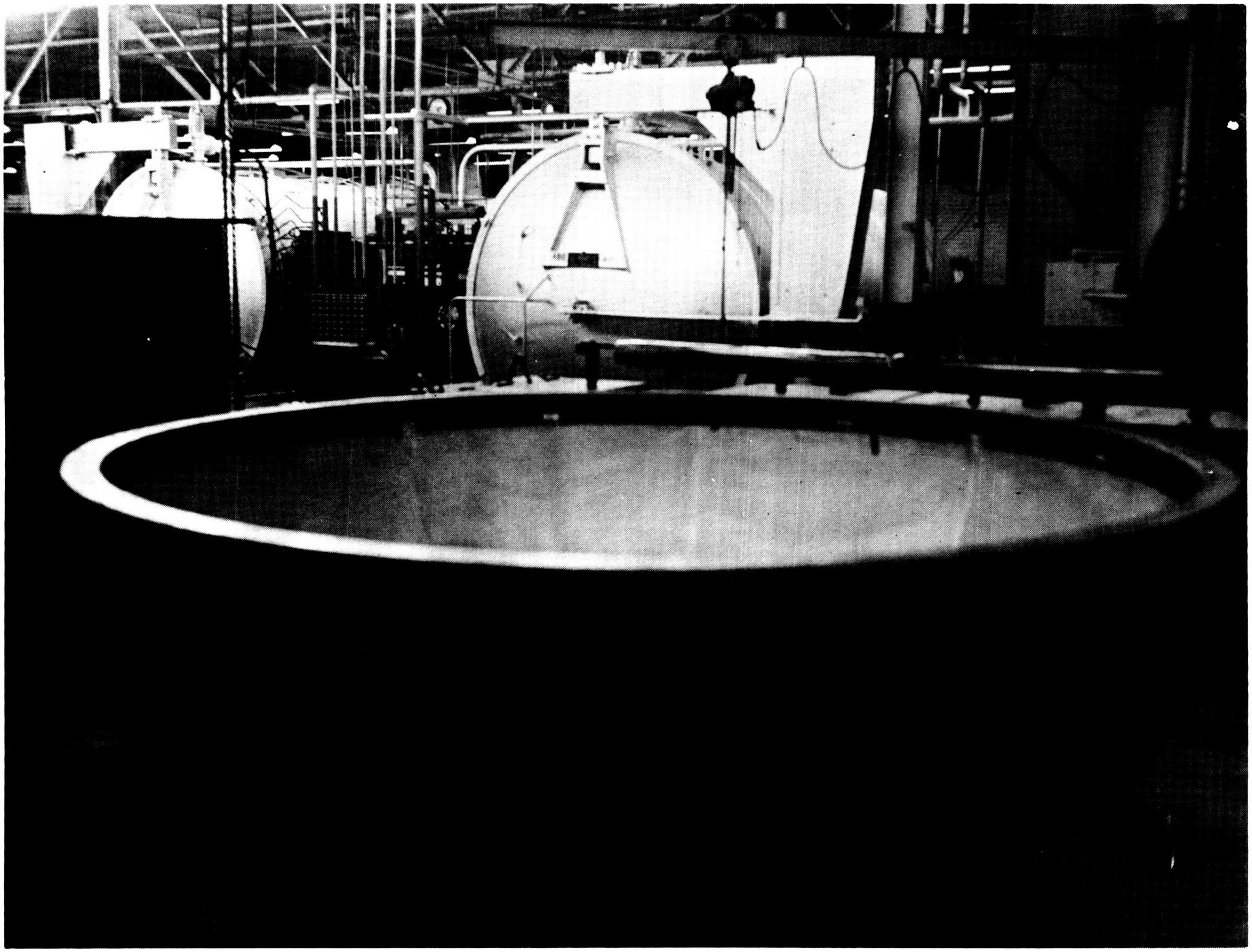
NAS 8-11900 BW-172457



PROJ. 78.57
NAS 8-11900

TYPICAL VACUUM BAG APPROACH TO APPLICATION OF AUTOCLAVE PRESSURE

FIG. 22
BWA-76591



PROJ. 78.57
NAS 8-11900

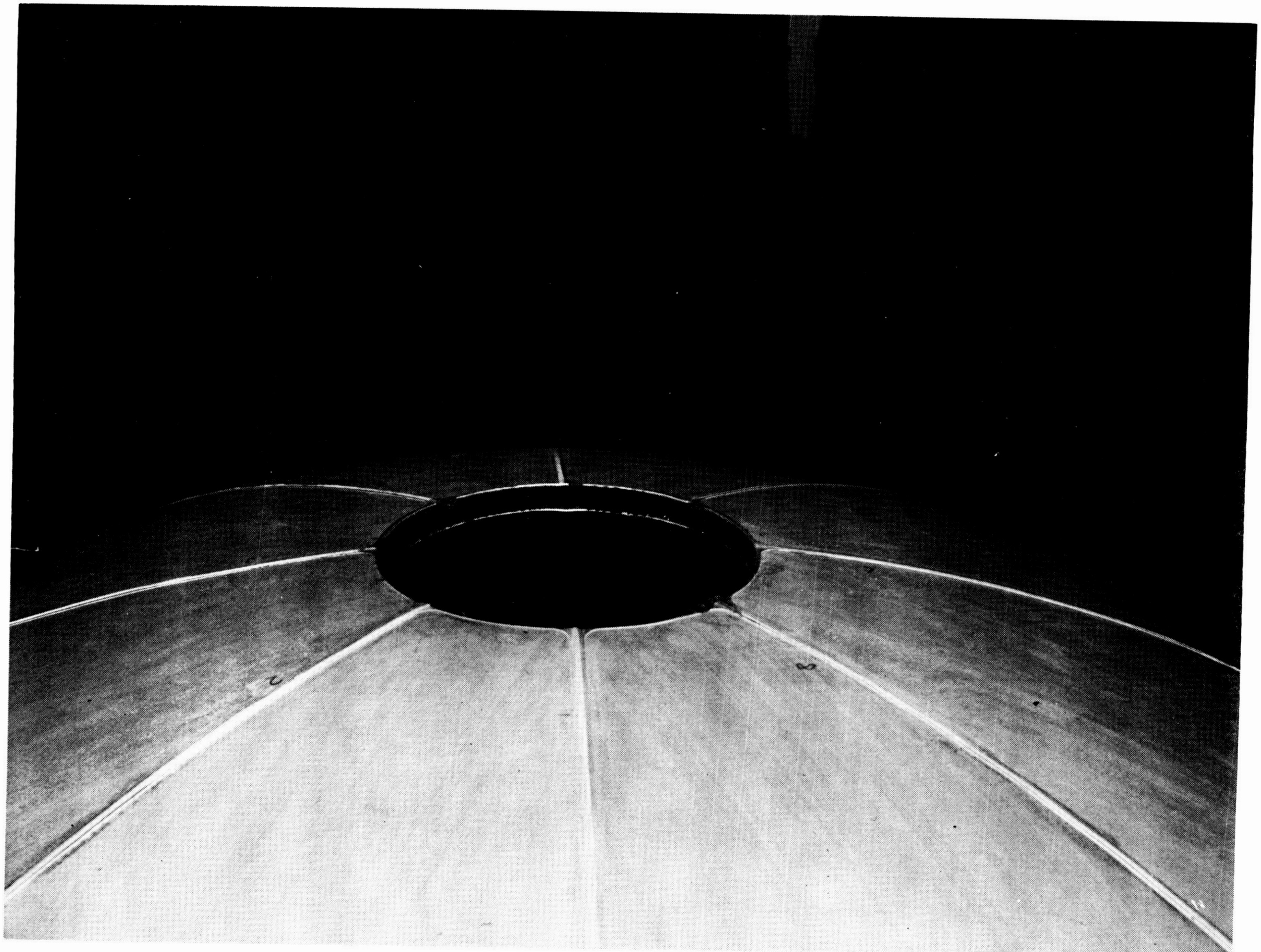
SHOWING ADHESIVE BONDED BULKHEAD ASSEMBLY STILL IN THE TOOL - AUTOCLAVES IN THE BACKGROUND

FIG. 23
BW-172458

PROJ. 78.57
NAS 8-11900

MR&T-SK717B INTERNAL VIEW

FIG. 24
BWA76687

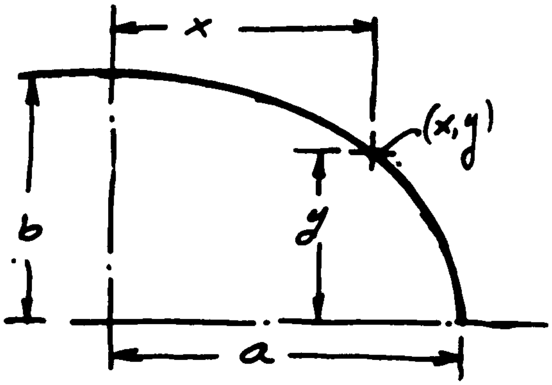


PROJ. 78.57
NAS 8-11900

MR&T-SK717B - POLAR CAP AREA - ADHESIVE BONDED ASSEMBLY

FIG. 25
BW-172459

PROJ. 78.57 MR&T-SK717B - EXTERNAL VIEW FIG. 26
NAS 8-11900 BWA-76636



BASIC CONTOUR

$b^2x^2 + a^2y^2 = a^2b^2$

$y = \frac{b}{a}\sqrt{a^2 - x^2}$ ----- I

FOR OUTSIDE MOLD LINE OF BULKHEAD

$a = 52.500 \qquad b = a\sqrt{2} = 37.125$

$y = \frac{37.125}{52.500}\sqrt{52.500^2 - x^2} = .70711\sqrt{(52.5)^2 - x^2}$ --- II

FOR WELD FIXTURE OUTSIDE MOLD LINE (OUTER SKIN) WITH ALLOWANCE FOR GROWTH.

$a = [52.500(1.00 - .001) - .060] = [52.500(.999) - .060]$

$= 52.3875$

$b = [37.125(1.00 - .001) - .060] = 37.0279$

$y = \frac{37.0279}{52.3875}\sqrt{52.3875^2 - x^2}$ - - - - - - III

FOR WELD FIXTURE OUTSIDE MOLD LINE (INSIDE SKIN) WITH ALLOWANCE FOR GROWTH

$a = [52.500(1.00 - .001) - 1.120] = 52.4475 - 1.120 = 51.3275$

$b = [37.125(1.00 - .001) - 1.120] = 37.0879 - 1.120 = 35.9679$

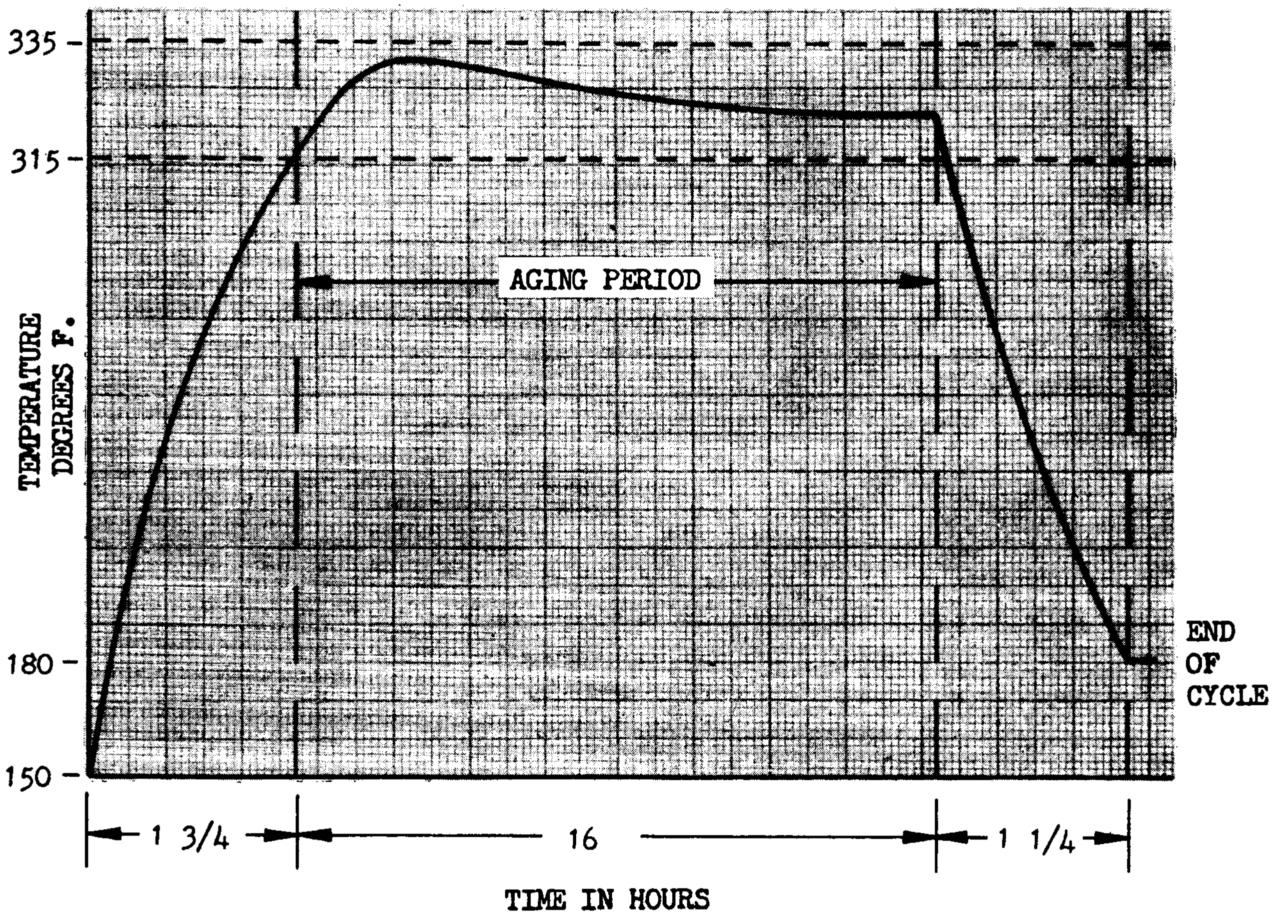
$y = \frac{35.9679}{51.3275}\sqrt{51.3275^2 - x^2}$ - - - - - - - - IV

CALC	[illegible]	[illegible]	REVISED	DATE
CHECK				
APR				
APR				

CONTRACT NO. NASA NAS 8-11900

Fig. 27 Development of Equations for the Trace of Bulkhead Outside Mold Lines

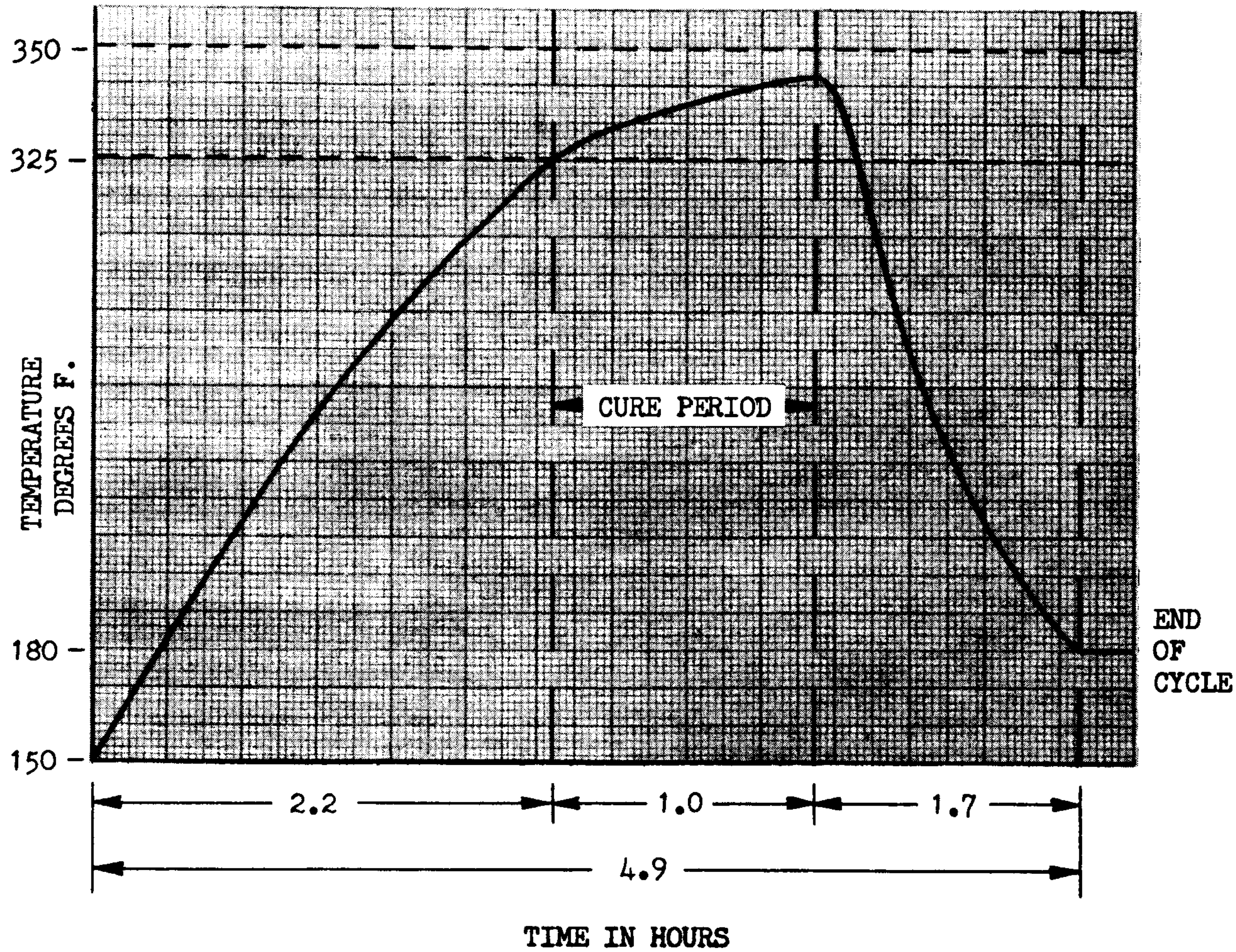
FIRST UNIT



PRESSURE - 60 PSIG
Pressurization started with vacuum bag evacuated to 26" Hg.
At 7 PSI positive pressure, the vacuum was ported to the atmosphere & autoclave pressure was increased to 60 PSIG.

Fig. 28 Aging Cycle - Outer Skin

FIRST UNIT

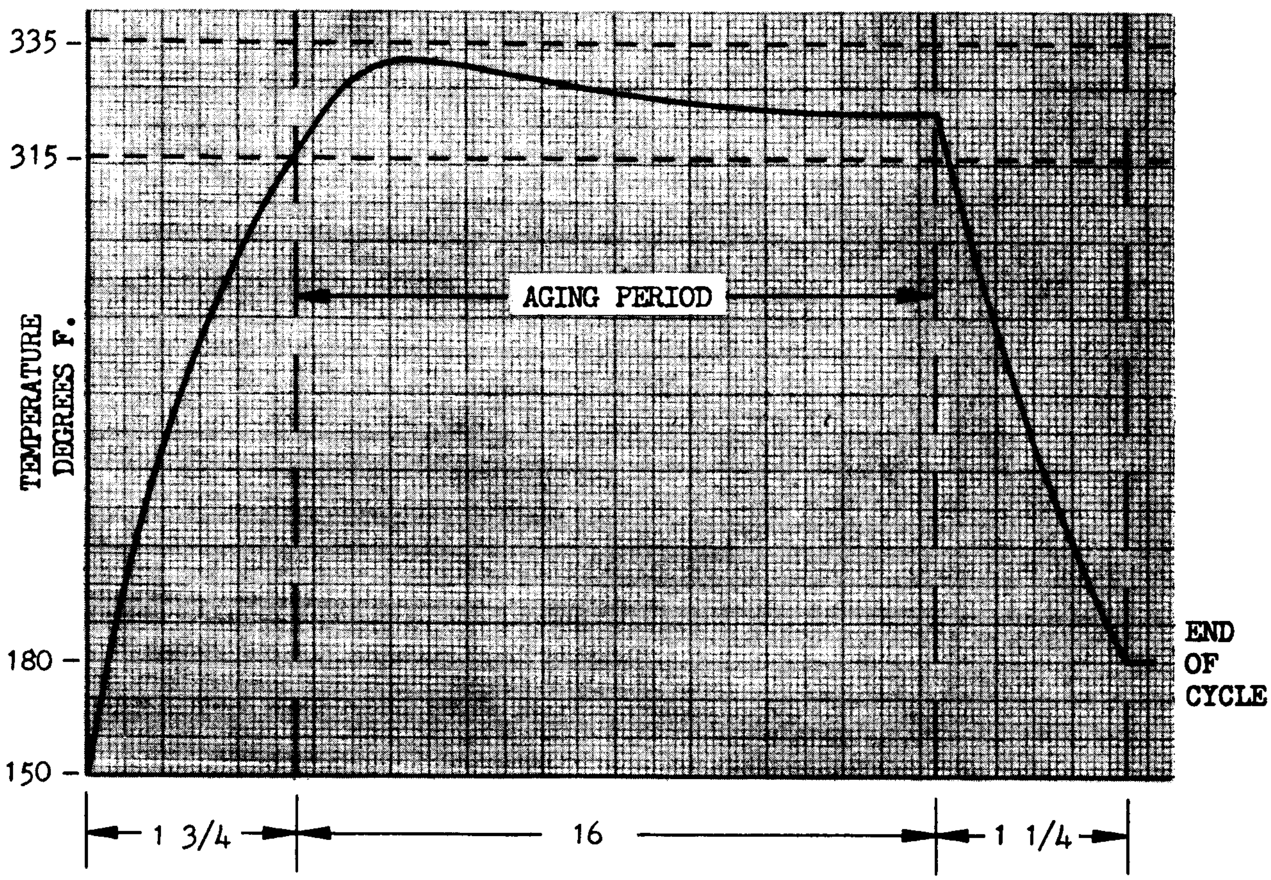


PRESSURE = 30 PSIG

Pressurization started with vacuum bag evacuated to 26" Hg. At 7 PSI positive pressure,the vacuum was ported to the atmosphere & autoclave pressure was increased to 30 PSIG.

Fig. 29 Cure Cycle - Outer Skin to Core Bonding

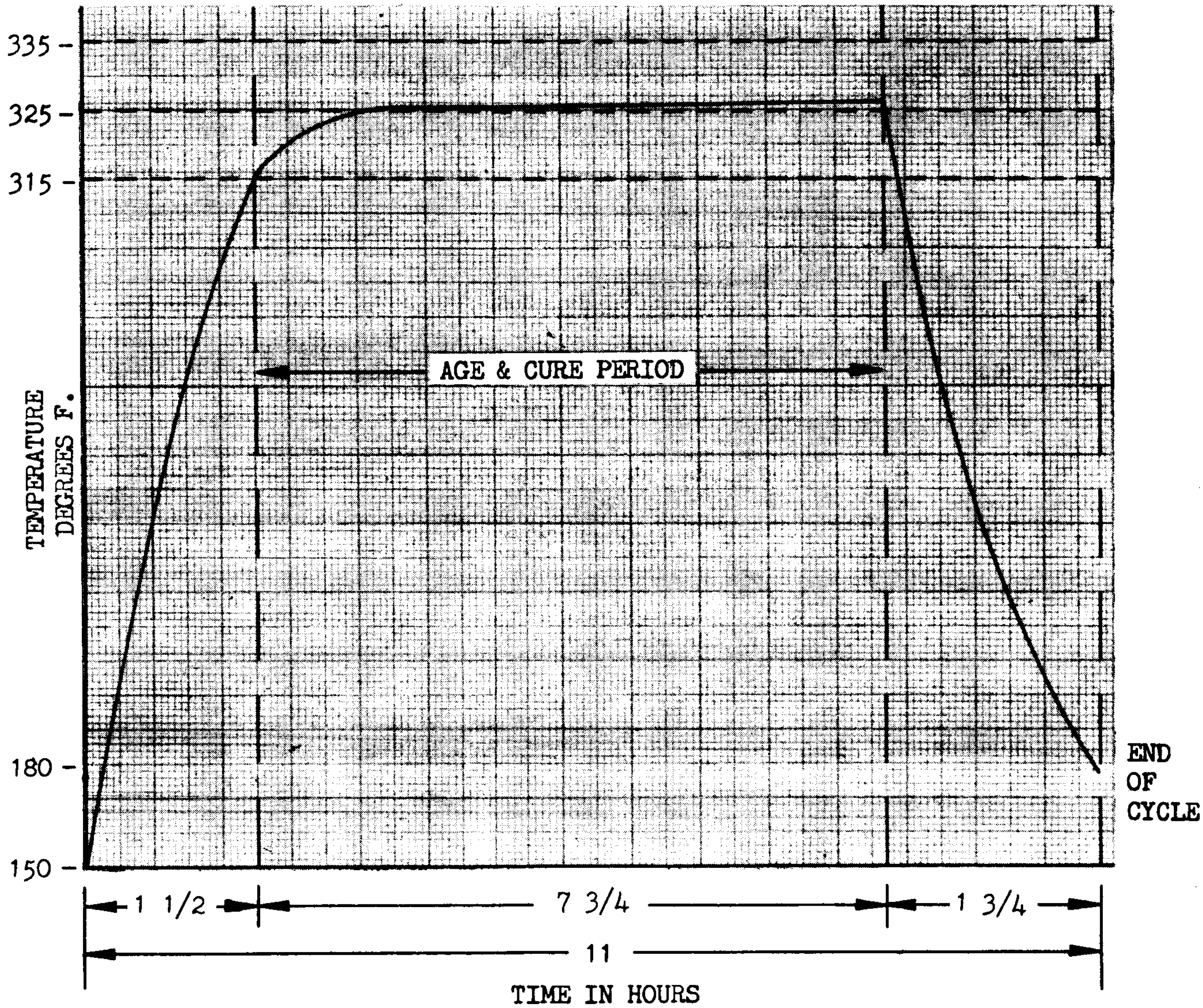
FIRST UNIT



PRESSURE - 60 PSIG MINIMUM
Pressurization started with vacuum bag evacuated to 26" Hg.
At approximately 7 PSI positive pressure the vacuum was ported to the atmosphere & autoclave pressure was increased to 60 PSIG.

Fig. 30 Aging Cycle - Inner Skin

FIRST UNIT

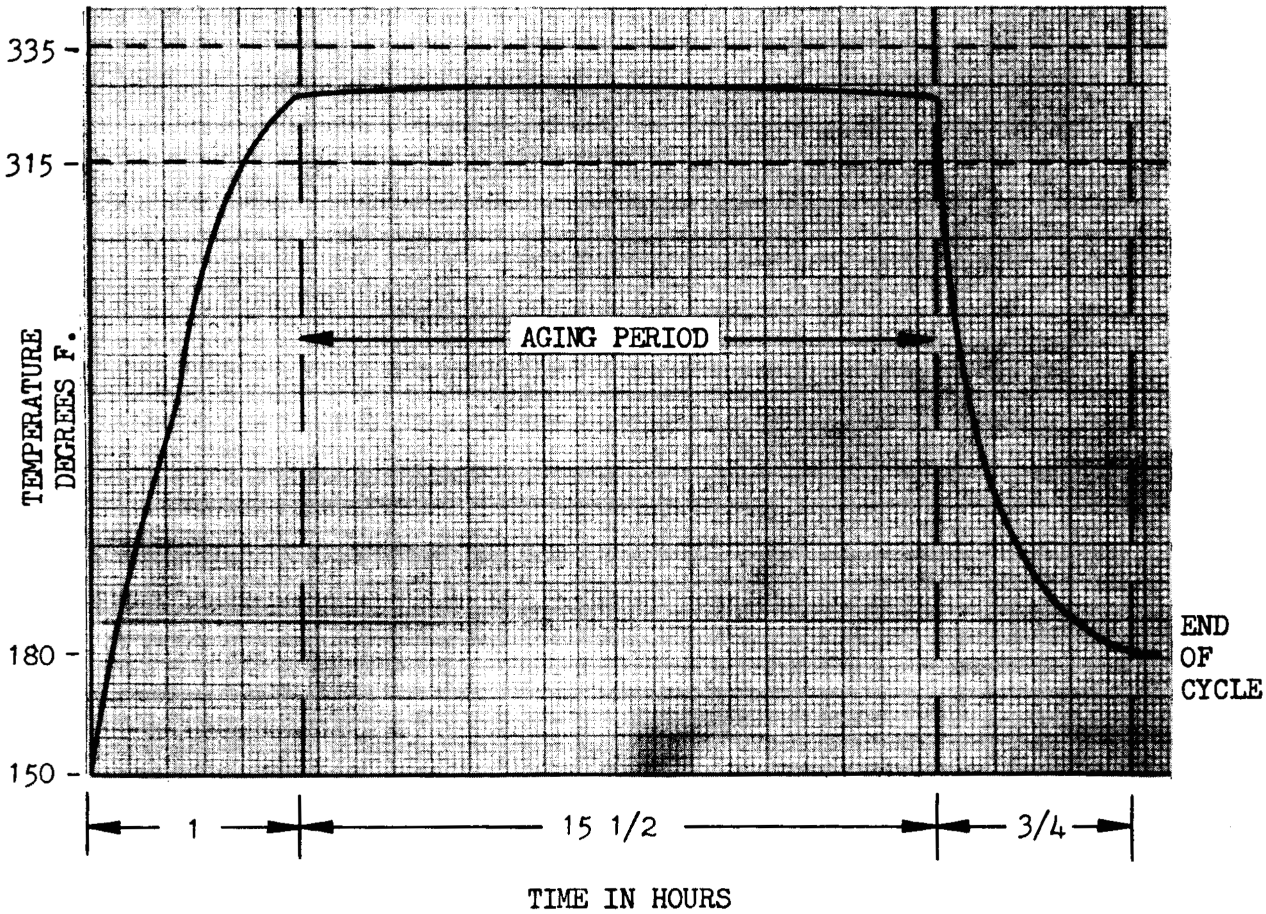


PRESSURE = 30 PSIG

Pressurization started with vacuum bag evacuated to 26" Hg. At 7 PSI positive pressure the vacuum was ported to the atmosphere and autoclave pressure was increased to 30 PSIG.

Fig. 31 Combined Adhesive Cure and Final Aging Cycle - Inner Skin

SECOND UNIT

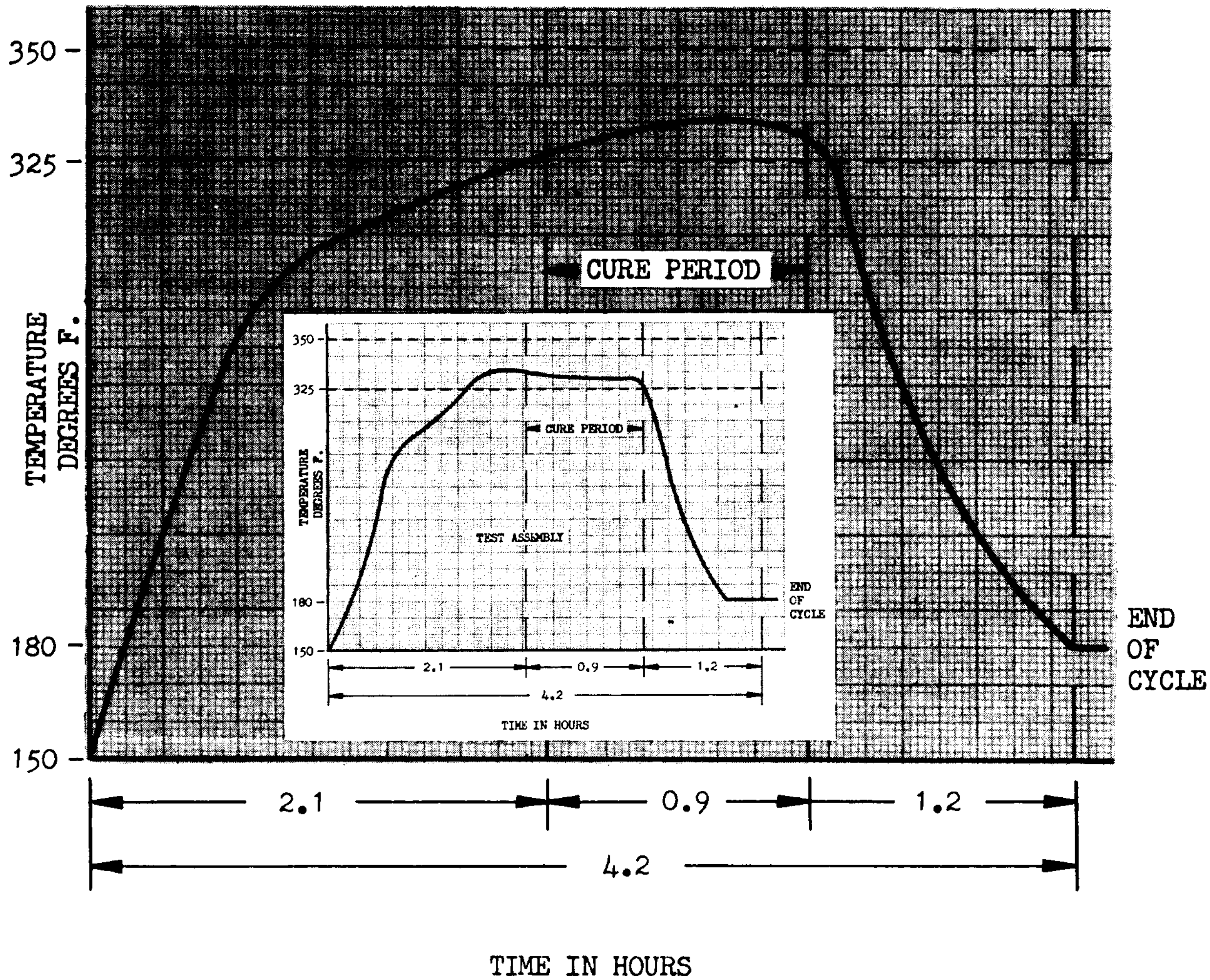


PRESSURE - 40 PSIG

Pressurization started with vacuum bag evacuated to 26" Hg. At 7 PSI positive pressure the vacuum was ported to the atmosphere & autoclave pressure was increased to 40 PSIG.

Fig. 32 Aging Cycle - Outer Skin

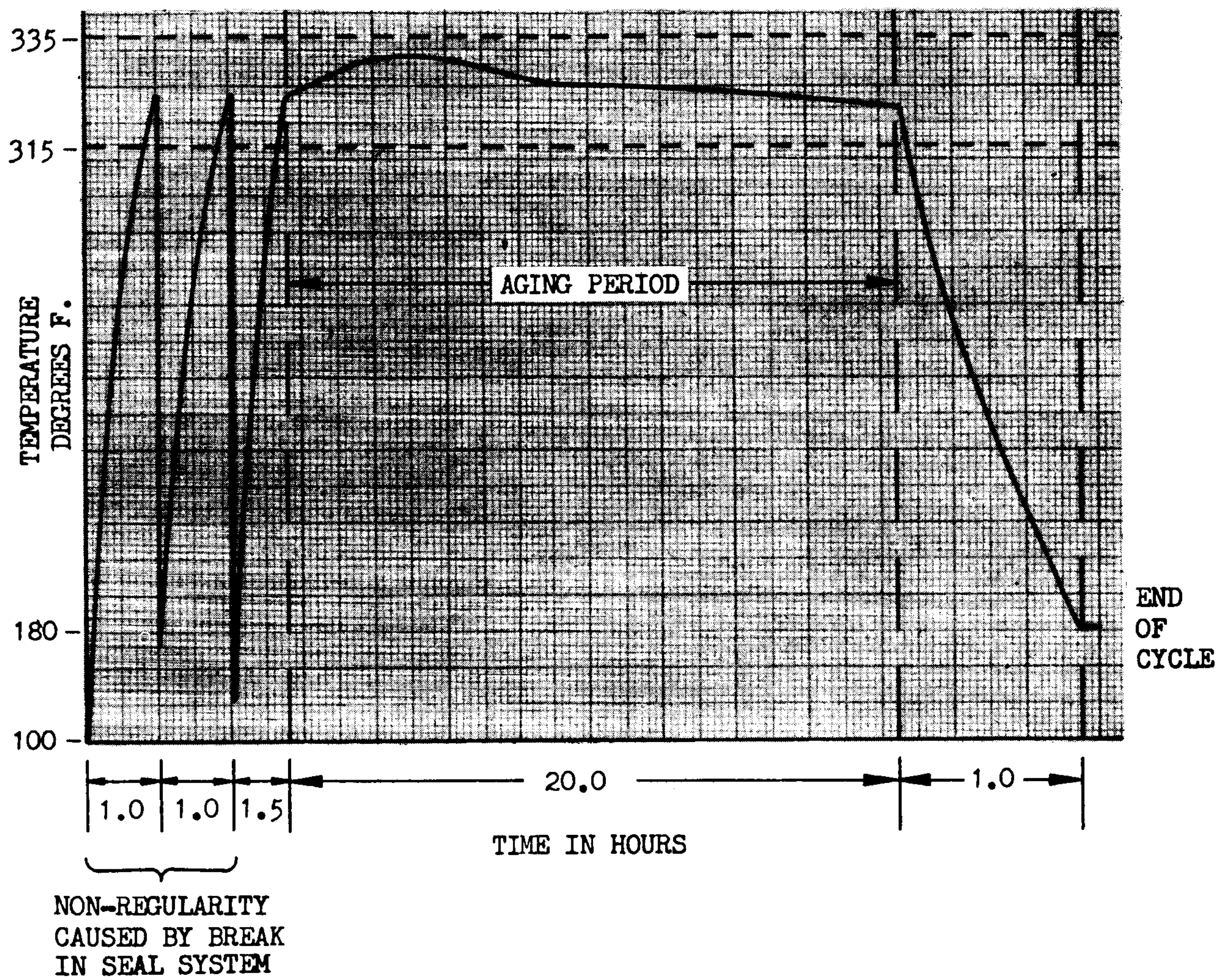
SECOND UNIT



PRESSURE - 30 PSIG
Pressurization started with vacuum bag evacuated to 26" Hg.
At 7 PSI positive pressure the vacuum was ported to the atmosphere & autoclave pressure was increased to 30 PSIG.

Fig. 33 Cure Cycle - Outer Skin to Core Bonding

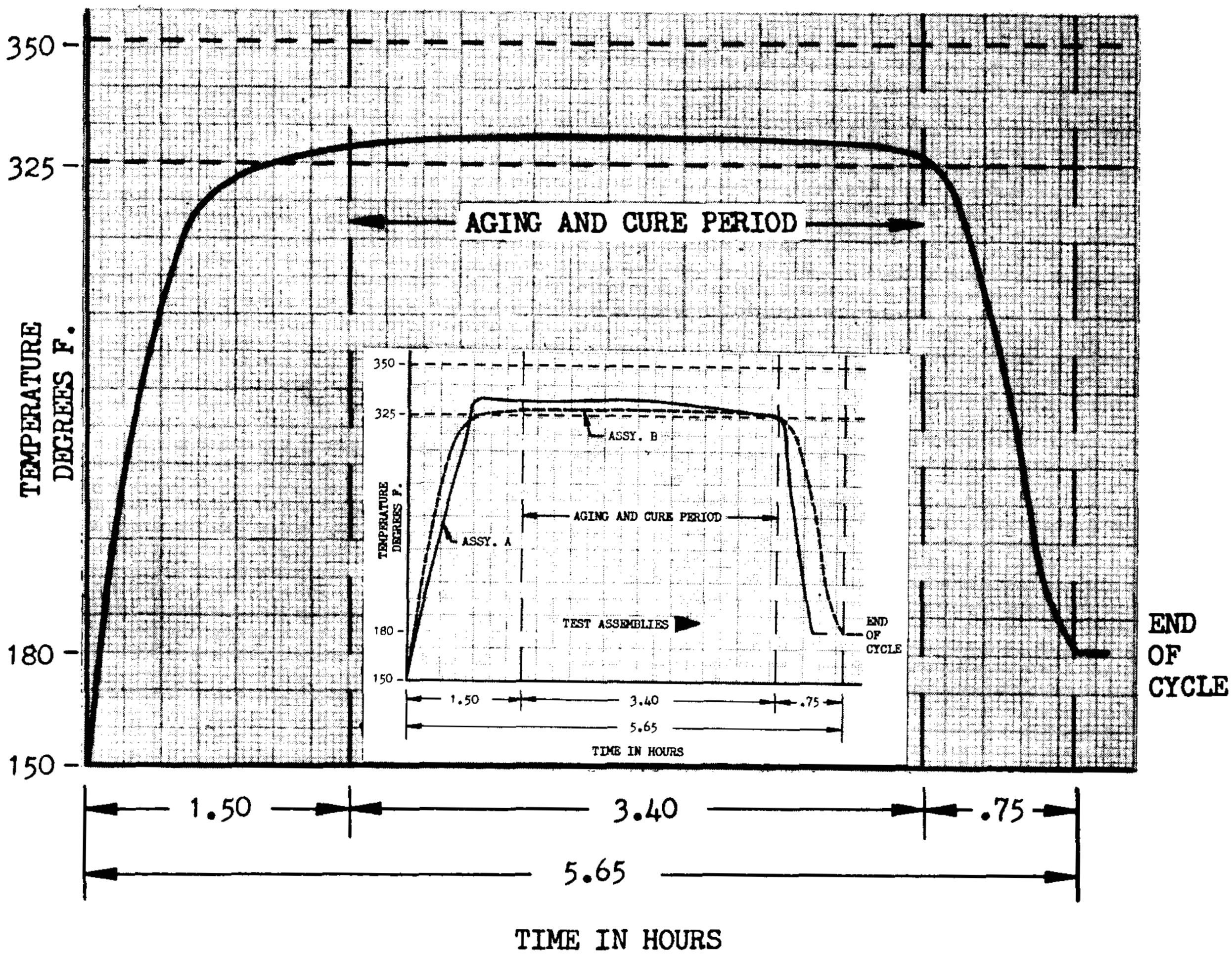
SECOND UNIT



PRESSURE - 40 PSIG
Pressurization started with vacuum bag evacuated to 26" Hg.
At 7 PSI positive pressure the vacuum was ported to the atmosphere & autoclave pressure was increased to 40 PSIG.

Fig.34 Aging Cycle - Inner Skin

SECOND UNIT



▶ TEST ASSEMBLY "A" - Cured initially with outer skin to core bond.
Recured with inner skin to core bond.

TEST ASSEMBLY "B" - Cured with inner skin to core bond only.

PRESSURE - 40 PSIG
Pressurization started with vacuum bag evacuated to 26" Hg.
At 7 PSI positive pressure the vacuum was ported to the atmosphere & autoclave pressure increased to 40 PSIG.

Fig. 35 Adhesive Cure Cycle - Inner Skin to Core - Pressure 40 PSIG

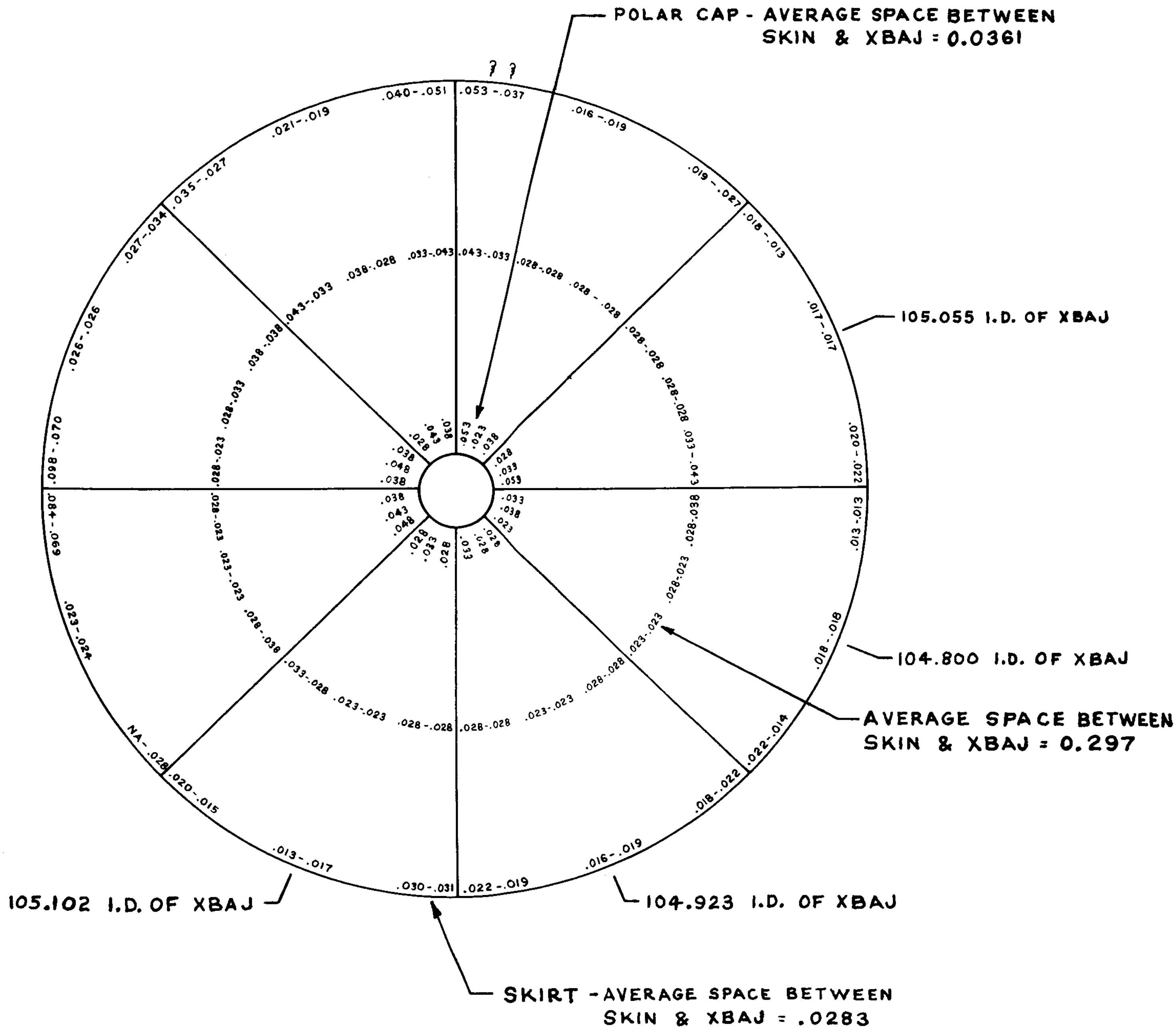


Fig. 36 First Unit-Comparison Between Outer Skin and the Forming-Aging Tool-Before Aging

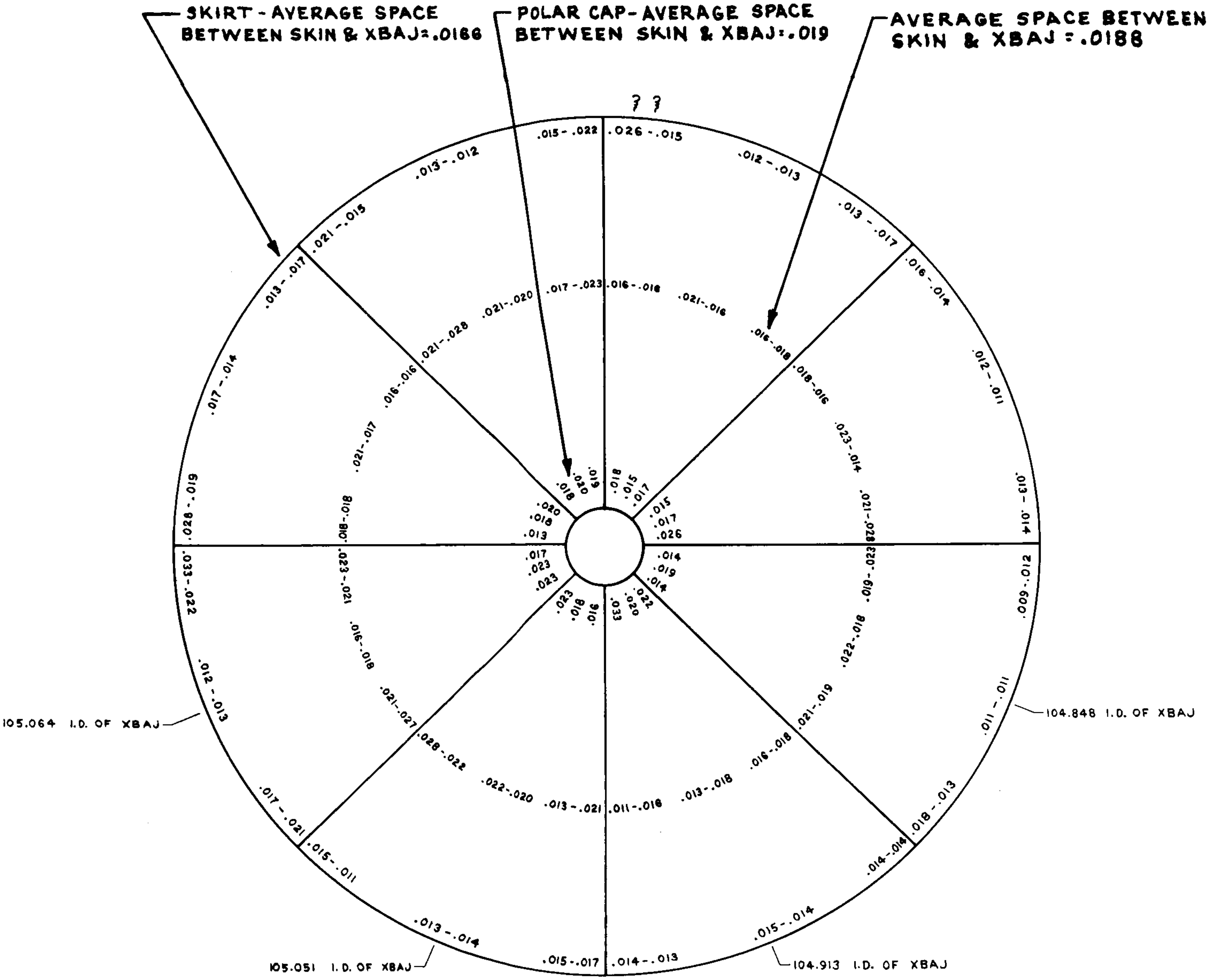


Fig. 37 First Unit - Comparison Between Outer Skin and the Forming-Aging Tool - After Aging

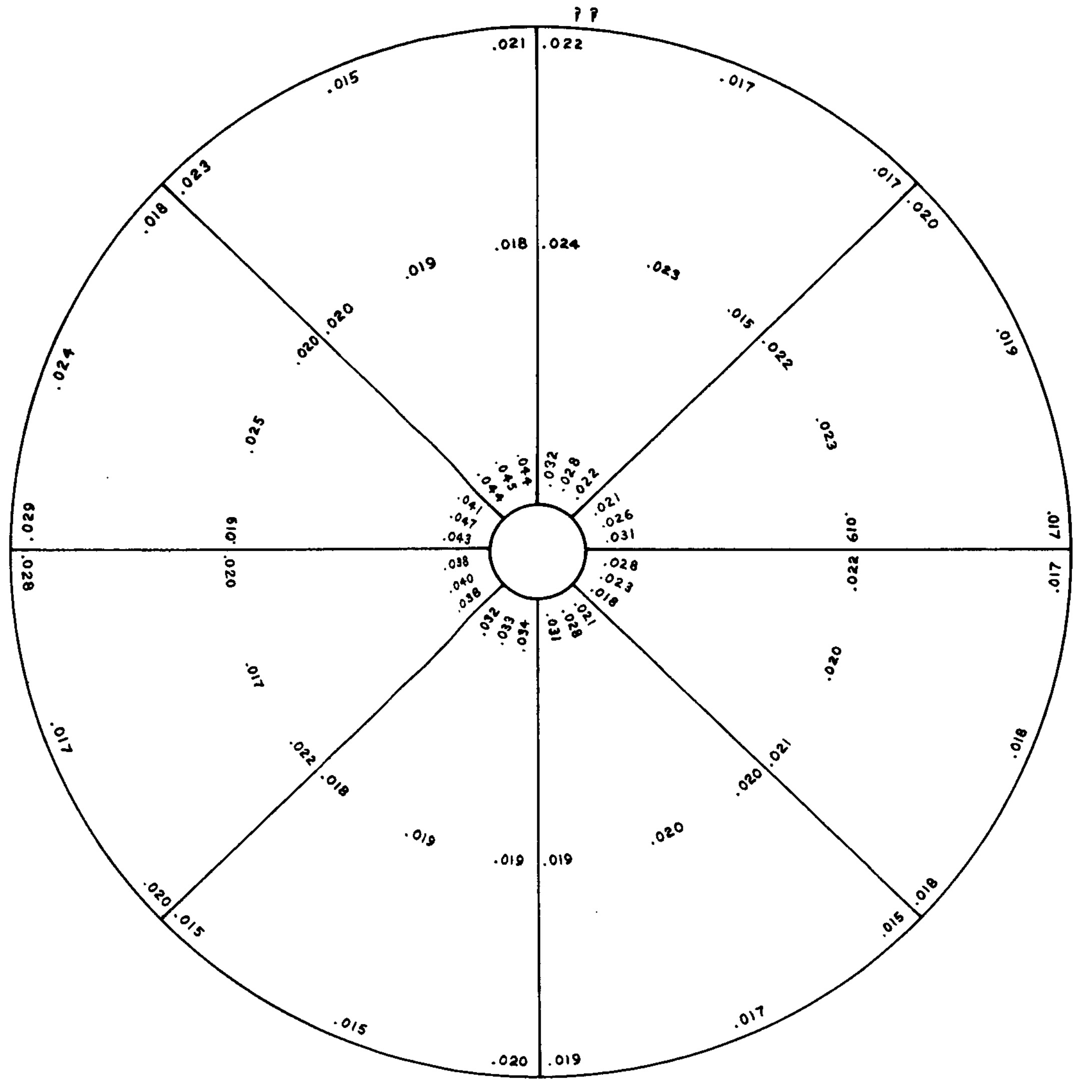


Fig. 38 First Unit - Comparison Between Bonded Assembly and the Forming-Aging Tool - Free State Measurements

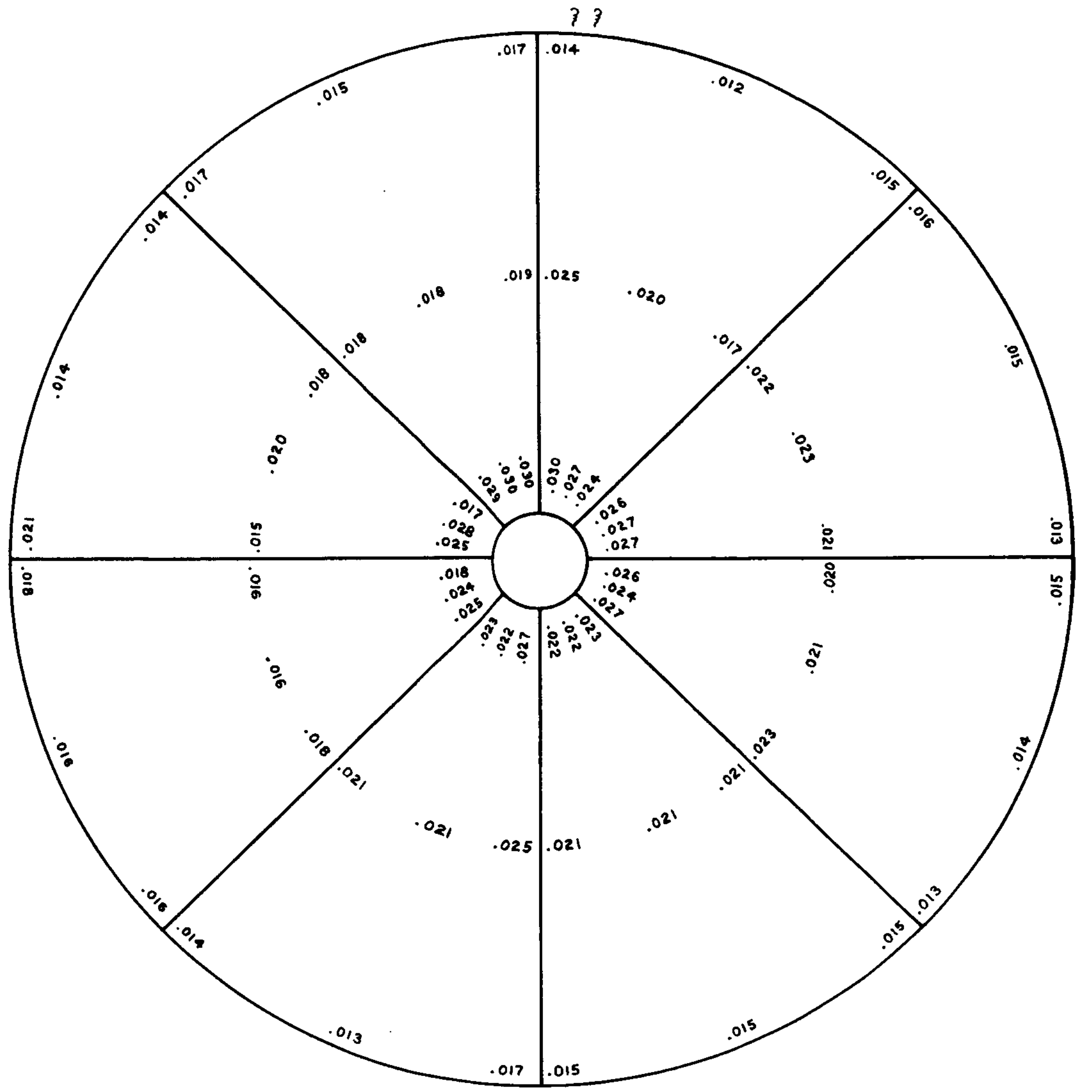


Fig. 39 First Unit - Comparison Between Bonded Assembly and the Forming-Aging Tool - Seated with 24"Hg. Vacuum.

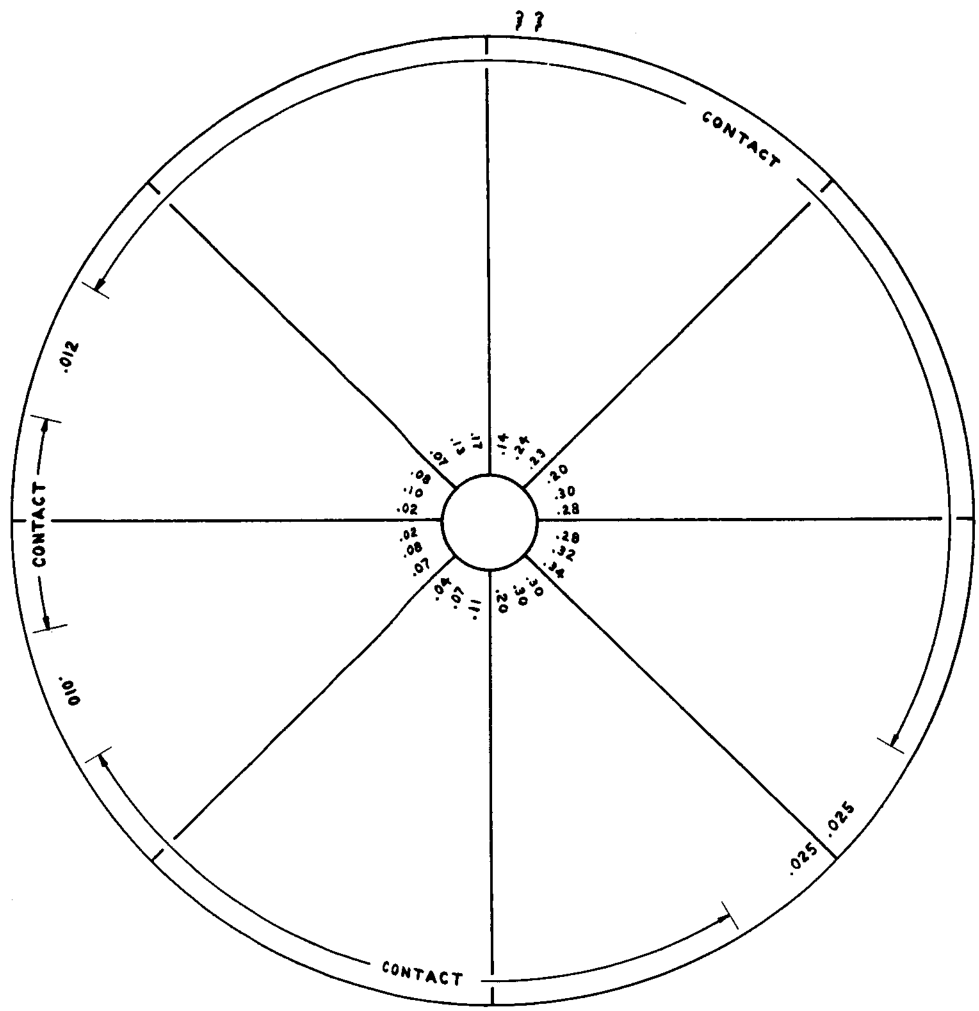
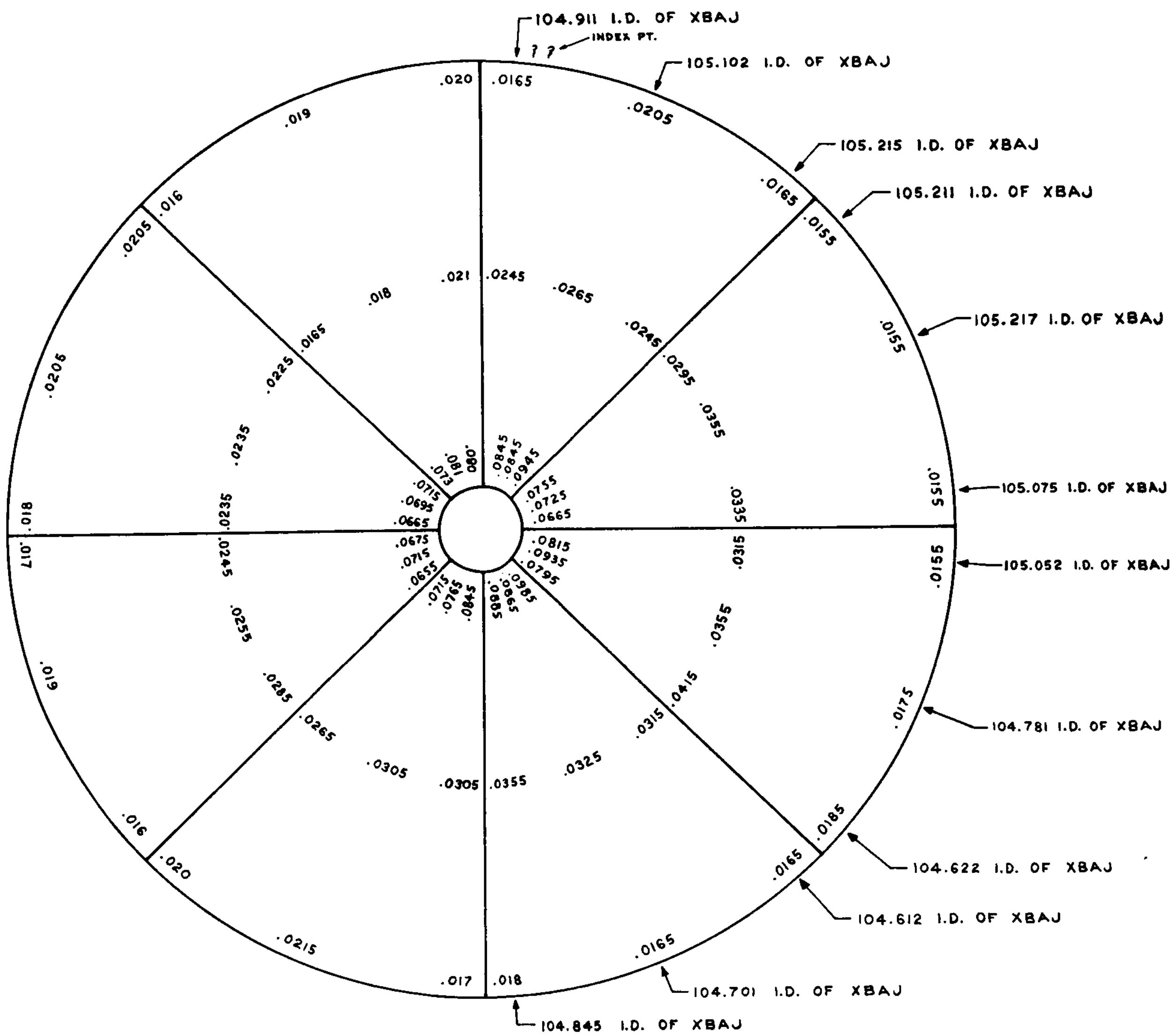
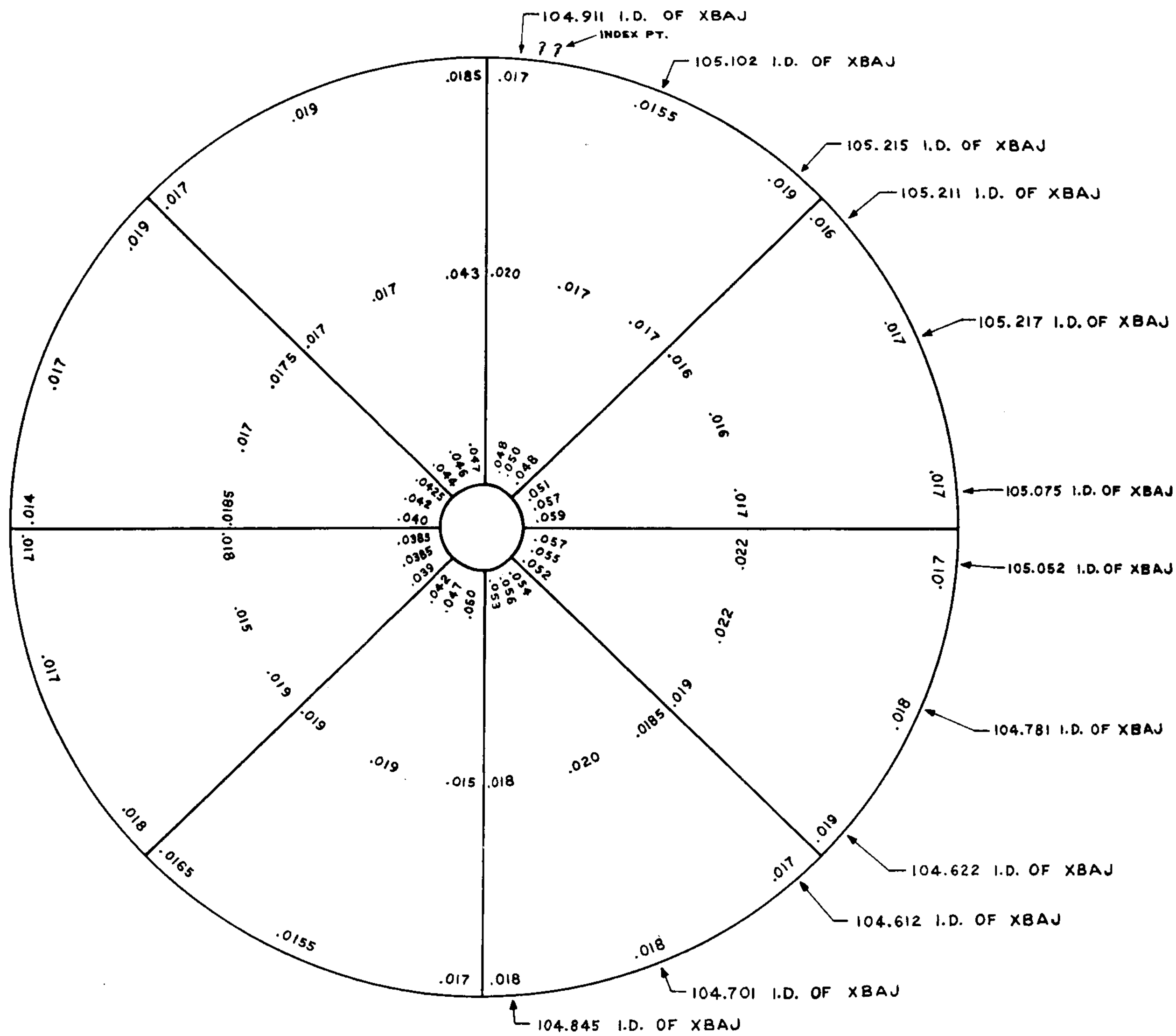


Fig. 40 Second Unit - Comparison Between Outer Skin and the Forming-Aging Tool - Before Aging



XBAJ - Concave Forming and Aging Tool

Fig. 41 Second Unit - Comparison Between Bonded Assembly and the Forming-Aging Tool - Free State Measurements



XBAJ - Concave Forming and Aging Tool

Fig. 42 Second Unit - Comparison Between Bonded Assembly and the Forming-Aging Tool - Seated with 26.5"Hg. Vacuum

	Index	2	3	4	5	6	7	8
COMPOSITE BULKHEAD ASSEMBLY NO. 1								
	.000 Mills ←							
OUTER SKIN (MR&T-SK717B-1) BEFORE AGING (SEE FIG. 36)								
Skirt	53-37	16-19	19-27	18-13	17-17	20-22	13-13	18
Mid-Point	43-33	28-28	28-28	28-28	28	33-43	28-38	28
Polar Cap	53	23	38	28	33	53	33	
OUTER SKIN (MR&T-SK717B-1) AFTER AGING (SEE FIG. 37)								
Skirt	26-15	12-13	13-17	16-14	12-11	13-14	11-09	11
Mid-Point	16-16	21-16	16-18	18-16	23-14	21-25	23-19	18
Polar Cap	18	15	17	15	17	26	14	
FREE STATE READINGS (ASSEMBLY SEATED WITH TWO (2) INCH								
Skirt	22	17	17	20	19	17	17	
Mid-Point	24	23	15	22	23	19	22	
Polar Cap	32	28	22	21	26	31	28	
ASSEMBLY SEATED WITH 24.0 INCHES H.G. VACUUM (SEE FIG.								
Skirt	14	12	15	16	15	13	15	
Mid-Point	25	20	17	22	23	21	20	
Polar Cap	30	27	24	26	27	27	26	
COMPOSITE BULKHEAD ASSEMBLY NO. 2								
FREE STATE READINGS								
Skirt	Contact ←						→	Con
Mid-Point	Not measured on Second Unit							
Polar Cap	140	240	230	200	300	280	280	
FREE STATE READINGS (ASSEMBLY SEATED WITH TWO (2) INCH								
Skirt	16.5	20.5	16.5	15.5	15.5	15.5	15.5	1
Mid-Point	24.5	26.5	24.5	29.5	35.5	33.5	36.5	3
Polar Cap	84.5	84.5	94.5	75.5	72.5	66.5	81.5	9
ASSEMBLY SEATED WITH 26.5 INCHES H.G. VACUUM (SEE FIG.								
Skirt	17	15.5	19	16	17	17	17	
Mid-Point	20	17	17	16	16	17	22	
Polar Cap	48	50	48	51	57	59	57	

● Indicates Weld Land Between Readings.

REV SYM:

E-3057

/ #

RISON OF ASSEMBLY AND COMPONENTS TO FORMING AGING TOOL

gs taken clockwise from index point with bulkhead polar cap down)

	9	10	11	12	13	14	15	16	17	18
-18	22-14	18-22	16-19	22-19	30-31	13-17	20-15	NA-28	23-24	84-69
-23	23-23	28-28	23-23	28-28	28-28	23-23	33-28	28-38	23-23	28-23
38	23	28	28	33	28	33	28	48	43	38
-11	13-18	13-13	14-15	13-14	17-15	14-13	11-15	21-17	13-12	22-33
-22	19-22	18-16	18-13	16-11	21-13	20-22	22-28	27-21	18-16	21-23
19	14	21	20	33	16	18	23	23	23	17

ES H.G. VACUUM (SEE FIG. 38)

18	18	15	17	19	20	15	15	20	17	28
20	21	20	20	19	19	19	18	22	17	20
23	18	21	28	31	34	33	32	38	40	38

39)

14	13	15	15	15	17	13	14	16	16	18
21	23	21	21	21	25	21	21	18	16	16
24	27	23	22	22	27	22	23	25	24	18

(SEE FIG. 40)

act	25	25	Contact	←			→	Contact	10	Contact	(
320	340	300	300	200	110	70	40	70	80	20	

ES H.G. VACUUM (SEE FIG. 41)

.5	18.5	16.5	16.5	18	17	21.5	20	16	19	17
5.5	41.5	31.5	32.5	35.5	30.5	30.5	26.5	28.5	25.5	24.5
3.5	79.5	98.5	86.5	88.5	84.5	76.5	71.5	65.5	71.5	67.5

42)

18	19	17	18	18	17	15.5	16.5	18	17	17
22	19	18.5	20	18	15	19	19	19	15	18
55	52	54	56	53	50	47	42	39	38.5	38.5

Fig. 43 Summation of Comparison Work

19	20	21	22	23	24	Max.	Min.	Avg. .000 Mills
98-70	26-26	27-34	35-27	21-19	40-51	98	13	28.3
28-23	28-33	38-38	43-33	38-25	33-43	43	23	29.7
38	48	38	28	48	38	53	23	36.1
28-19	17-14	13-17	21-15	13-12	15-22	28	09	16.6
18-18	21-17	16-16	21-28	21-20	17-23	28	11	18.8
13	18	20	18	20	19	33	13	19
29	24	18	23	15	21	29	15	19.6
19	25	20	20	19	18	25	15	20.2
43	47	41	44	45	44	47	18	32.8
21	14	14	17	15	17	21	12	15.3
15	20	18	18	18	19	25	15	23.0
25	28	17	29	30	30	30	17	25.0
ontact	12	Contact ←		→	Contact	25	10	15.6
20	100	80	70	130	170	340	100	166
18	20.5	20.5	16	19	20	21.5	15.5	17.79
23.5	23.5	22.5	16.5	18	21	41.5	16.5	24.07
66.5	69.5	71.5	73	81	80	98.5	65.5	78.52
14	17	19	17	19	18.5	19	14	17.25
18	17	17.5	17	17	43	43	15	19.06
40	42	42.5	44	46	47	59	38.5	48.14

Sheets

3#

INS 438 W R13

THE BOEING COMPANY
MILITARY AIRPLANE DIVISION WICHITA BRANCH
WICHITA, KANSAS. 67210

QUALITY CONTROL LABORATORY REPORT Q 48358

Date 9-22-65 Submitted by 3070 - Ray Cox (DEPT. NO. / INSP. OR SHOP SUPV.) Prepared by 4810 - F. Liscum (DEPT. NO. / NAME / PHONE)

Description: R.N. Part No. MRNT-SK717B P.O. Quantity Rec'd 1

Material Honeycomb Dome Assembly Vendor

No. of Samples No. of Pieces Spec. No. Copies to 3070 - RCox 1cc (DEPT. NO. / NAME)
3070 - HBuchanan 1cc
USAF - Chief,Q.C. 1cc

Information Requested Make radiographic examination of crown and dome area.

FCL:mm

HONEYCOMB DOME ASSEMBLY

One honeycomb dome assembly, P/N MRNT-SK717B, was submitted to the Quality Control Laboratory for radiographic examination of the crown and skirt area.

Radiographic examination showed that the adhesive was evenly distributed. All splices were well fitted and bonded. There were no crushed cells or node separation. The general quality of the core was excellent.

Linear porosity and lack of penetration were seen as the main defects on radiographs of the welds. Short pieces of thermocouple wire were also shown on the radiographs and were visible at the base of welds numbered 1, 7 and 7B. None of the weld defects appeared to be more than 30% of the weld thickness.

The films were filed in the Quality Control Laboratory. The part was returned to 3070 - Ray Cox.

Prepared by F. C. Liscum Approved by O.R. Borngesser

Figure 44

S 438 W R 1

THE BOEING COMPANY
MILITARY AIRPLANE DIVISION - WICHITA BRANCH
WICHITA, KANSAS, 67210

QUALITY CONTROL LABORATORY REPORT Q 50947

Date 11-18-65 Submitted by 3070 - Ray Cox (DEPT. NO. / INSP. OR SHOP SUPV.) Prepared by 4810 - F. Liscum (DEPT. NO. / NAME / PHONE)

Description: R.N. ______ Part No. MRST-SK717B P.O. ______ Quantity Rec'd ______

Material Honeycomb Dome Assembly Vendor ______

No. of Samples 1 No. of Pieces 1 Spec. No. ______ Copies to (DEPT. NO. / NAME)
3070 - RCox ~~1cc~~
3070 - HBuchanan 1cc
USAF - Chief,Q.C. 1cc

Information Requested Make radiographic inspection of crown area, skirt area and one 14 x 17 inch area in center of each gore.

FCL:mm

HONEYCOMB DOME ASSEMBLY

One honeycomb dome assembly, part number MRST-SK717B, serial number 2, was submitted to the Laboratory for radiographic examination.

Radiographic examination was made of the skirt and crown areas and of a 14 x 17 inch area in the center of each gore. This examination showed that the adhesive was evenly distributed. All splices were well fitted and bonded. There were no crushed cells or node separations. The general quality of the core was good.

The weld would not meet current Military weld standards due to linear porosity and/or lack of penetration.

The films were filed in the Quality Control Laboratory. The dome was returned to 3070 - Ray Cox.

Prepared by F.C. Liscum Approved by O.R. Borngesser

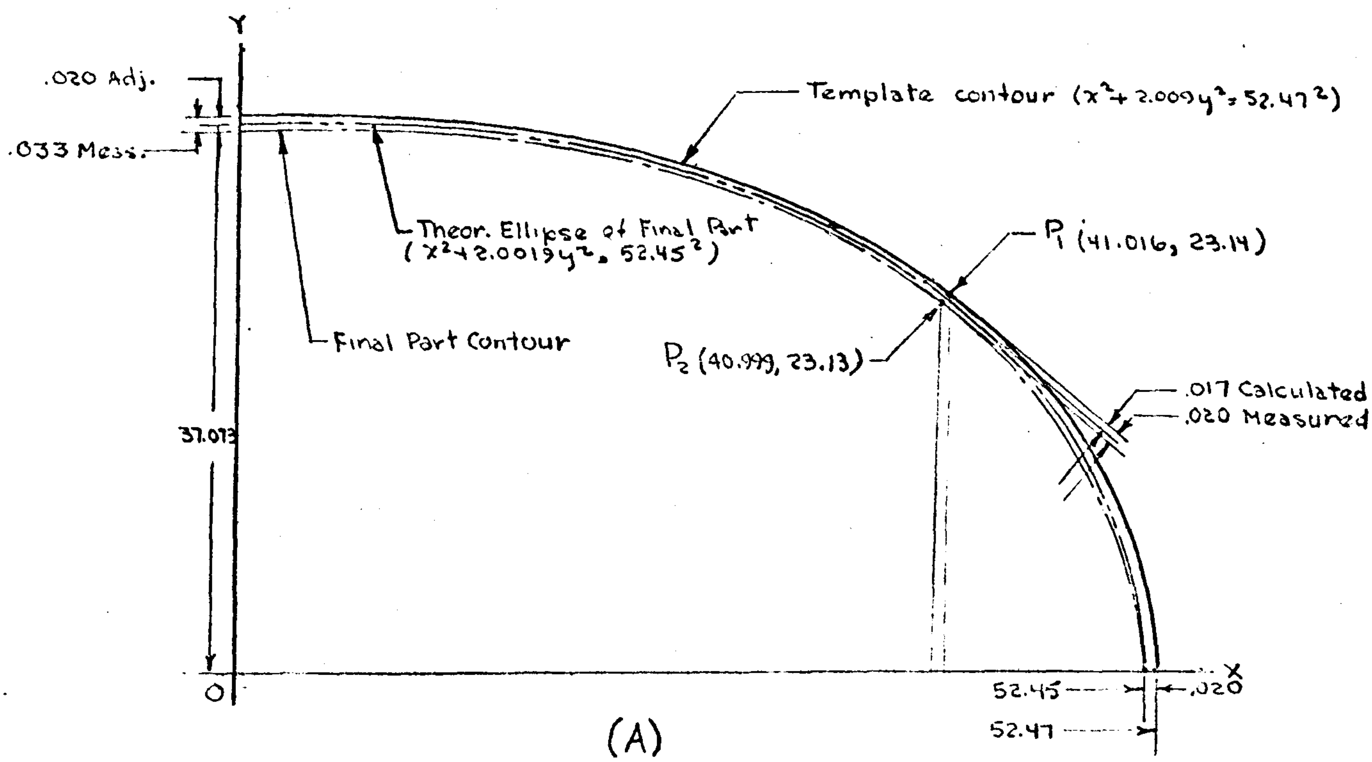
Figure 45

CONFIGURATION ANALYSIS

Measurement of the completed part was made by the use of a template developed by the equation of the bulkhead, $X^2 + 2Y^2 = 52.5^2$, with .030" step back along the contour to allow for the weld land. This set back produced a new major axis, a = 52.47" and a new minor axis, b = 37.093". From the new a and b, the ellipse equation becomes:

$$\frac{X^2}{2753.101} + \frac{Y^2}{7375.591} = 1$$

Eq. (1) or $X^2 + 2.0009Y^2 = 52.47^2$



(A)

Measurement to the finished part, from and normal to the template, at the pole was .033" (average); measurement at the major axis was .020" (average). At a point P_1 with Y = 23.14", the distance to the part was .020" (average). (A) The template was set to coincide with the major and minor axes of the finished part.(Ref. Tabulation, Fig. 43).

Fig. 46
Pg.1 of 2

Establishing an equation of the theoretical surface of the part using these measurements and adjusting for the polar depression as follows:

$$a = 52.470'' - .020'' = 52.45'' \quad \text{and} \quad b = 37.093'' - .020'' = 37.073''$$

Eq. (2) $$\frac{X^2}{52.45^2} + \frac{Y^2}{37.073^2} = 1 \quad \text{or} \quad X^2 + 2.0016Y^2 = 52.45^2$$

To determine the actual deviation of the surface of the part at point P_1 from the template to the theoretical surface at P_2 we substitute $Y = 23.14$ in Eq.(1):

$$X = -\sqrt{52.47^2 - 2.0009\ (23.14)^2}$$

$$X = 41.016''$$

The slope of a line normal to the template at P_1 (41.016, 23.14) is

$$\frac{a^2Y_1}{b^2Y_1} = \frac{52.47^2 \times 23.14}{37.093^2 \times 41.016} = 1.133$$

Equation of the line normal at $P_1 = Y - Y_1 = M\ (X - X_1)$

Eq. (3) $$1.133X - Y - 23.331 = 0$$

P_2 the intersection of the normal line with the theoretical surface is found by simultaneous solution of the equations of the ellipse (2) and the line (3). This yields $X = 40.999''$ and $Y = 23.13''$.

Using the equation of distance between two points

$$d = -\sqrt{(X - X_1)^2 + (Y - Y_2)^2}$$

we have $D = .017''$

a difference from the measured distance, .020", of only .003".

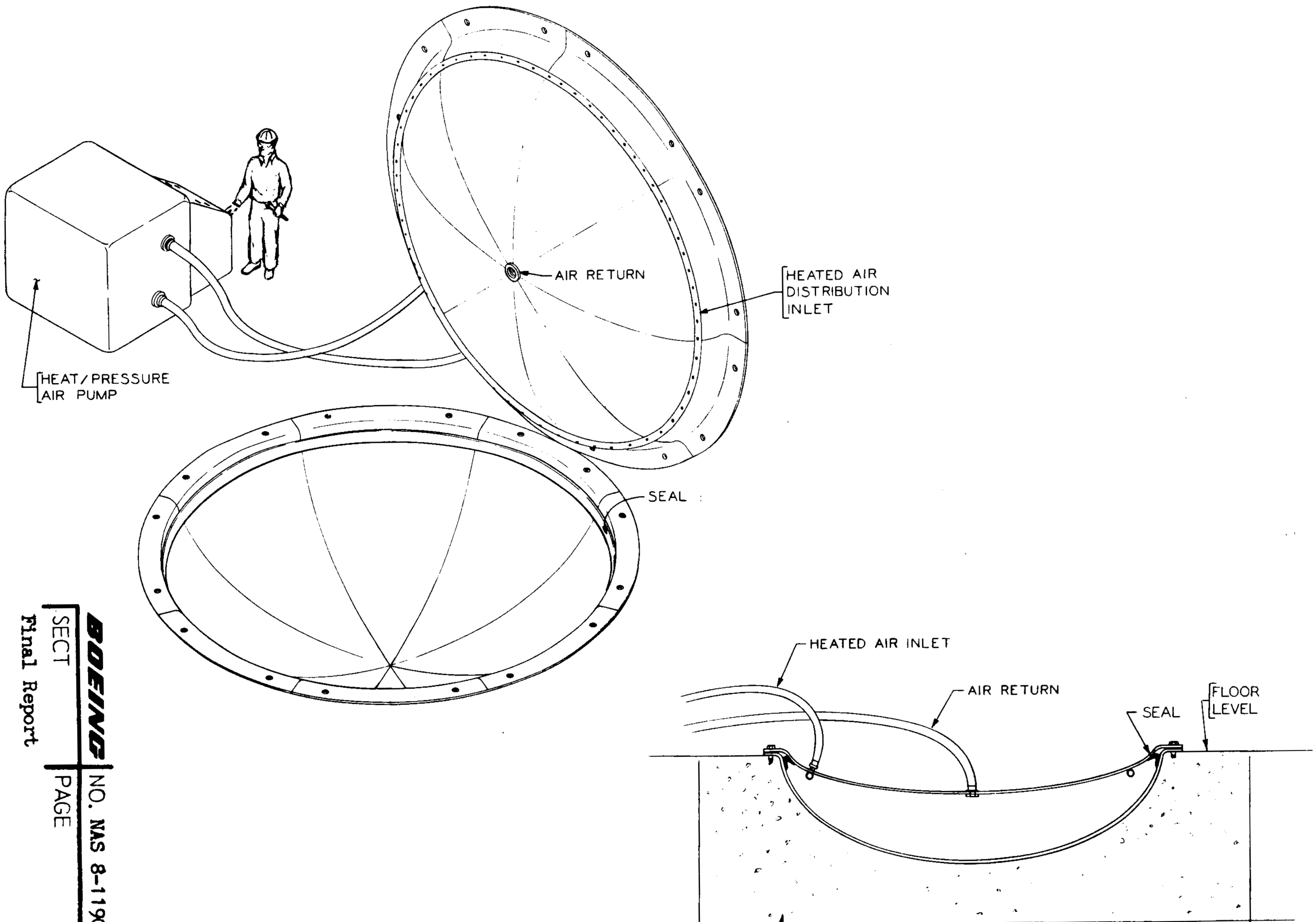


Fig. 47 Large Scale Assembly Forming, Aging and Bonding Tool Concept Sketch